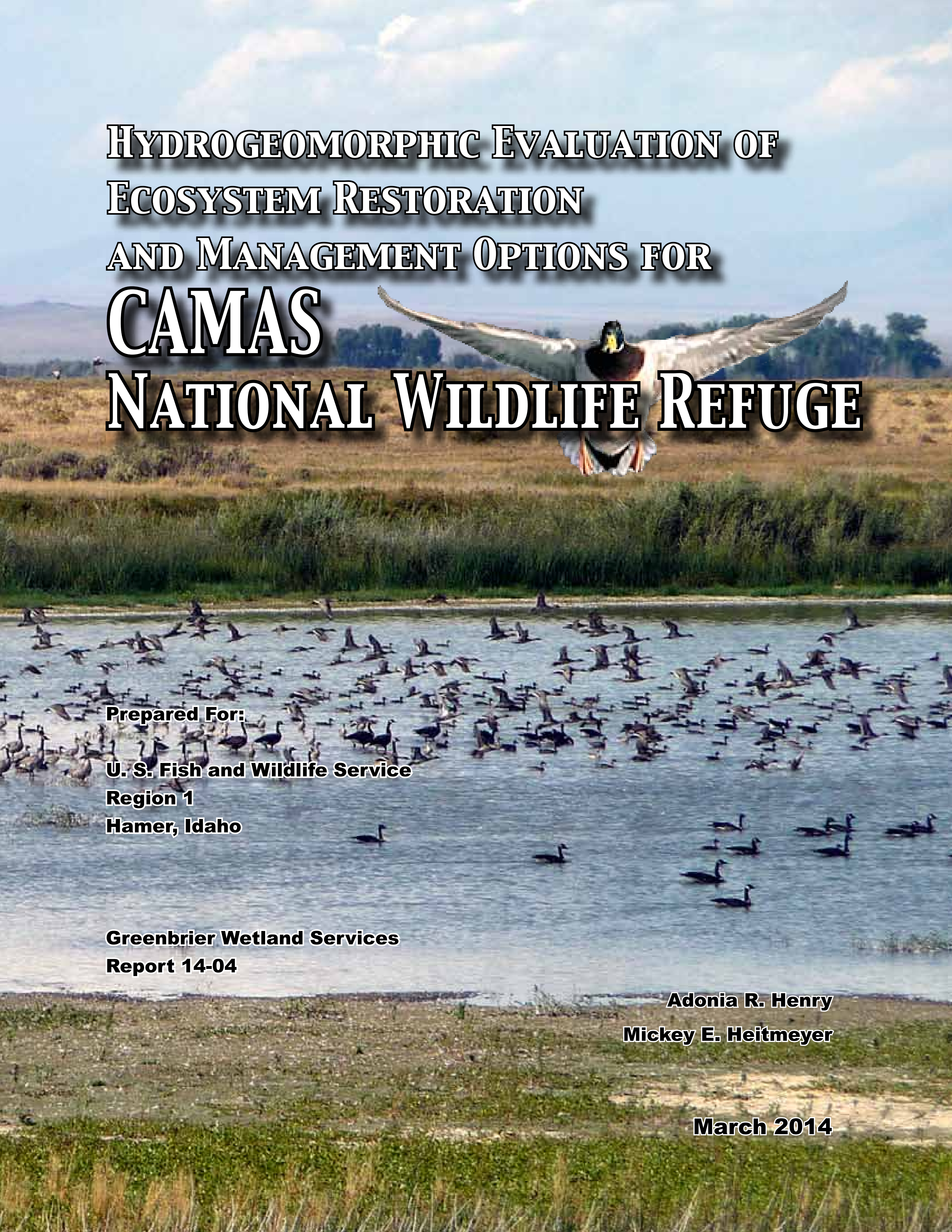

Hydrogeomorphic Evaluation of Ecosystem Restoration and Management Options for

CAMAS National Wildlife Refuge

Prepared For:

U. S. Fish and Wildlife Service
Region 1
Hamer, Idaho

Greenbrier Wetland Services
Report 14-04

Adonia R. Henry

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March 2014

HYDROGEOMORPHIC EVALUATION OF ECOSYSTEM RESTORATION AND MANAGEMENT OPTIONS FOR CAMAS NATIONAL WILDLIFE REFUGE

Prepared For:

U. S. Fish and Wildlife Service
Region 1
Camas National Wildlife Refuge
Hamer, Idaho

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Publication No. 14-04

Suggested citation:

Henry, A. R., and M. E. Heitmeyer. 2014. Hydrogeomorphic evaluation of ecosystem restoration and management options for Camas National Wildlife Refuge. Prepared for U. S. Fish and Wildlife Service, Region 1, Camas NWR, Hamer, ID. Greenbrier Wetland Services Report 14-04, Blue Heron Conservation Design and Printing LLC, Bloomfield, MO.

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Adonia Henry

EXECUTIVE SUMMARY


Adonia Henry

Camas National Wildlife Refuge (CNWR) includes 10,578 acres of diverse wetland and upland habitats in the Eastern Snake River Plain (ESRP) along eight miles of Camas Creek in Jefferson County, Idaho. Dominant landform characteristic of the refuge is the shallow Mud Lake alluvial aquifer formed from lacustrine deposits of pluvial Lake Terreton and its juxtaposition with basalt lava flows and alluvial processes on Camas Creek. Surface water from Beaver, Camas, and Warm Creek flows through CNWR to Mud Lake, a topographically closed terminal basin with no surface water outflow to the Snake River.

CNWR was established in 1937; then existing agricultural "improvements" were modified and expanded to develop infrastructure to manage wetland habitats for migratory birds. Prior to developments at and surrounding CNWR, water levels in the lower Beaver-Camas subbasin (including Mud Lake and CNWR) were characterized by seasonal, annual, and long-term multi-decadal fluctuations in the depth, duration and extent of flooded habitats. During wet years, Camas Creek overflowed its banks and Mud Lake and the surrounding herbaceous wetlands contained extensive surface water area that supported large numbers of migrating and breeding waterbirds. In contrast, during dry years, less water was present and although the area could not support as many waterbirds, these dry conditions sustained important wetland processes.

During 2010, the USFWS started a Comprehensive Conservation Plan (CCP) for CNWR. Most of the CCP's completed for NWR's to date have highlighted ecological restoration as a primary goal. However, limited information typically is provided in the CCPs on how restoration will be accomplished in the existing and often highly modified regional landscape. Historical conditions (those prior to substantial human-related changes to the landscape) are often selected as the benchmark condition (Meretsky et al. 2006), but restoration to these historical conditions may not be well understood, feasible, or cost-effective, thereby compromising success of restoration actions.

This report provides a hydrogeomorphic (HGM) evaluation to help identify future options for ecosystem restoration and management of CNWR. The HGM approach objectively seeks to understand: 1) how this ecosystem was created, 2) the fundamental physical and biological processes that historically "drove" and "sustained" the structure and functions of the system and its communities, and 3) what changes have occurred that have caused degradations and that might be reversed and restored to historical and functional conditions within a changing environment. This HGM approach also provides a basis to help future efforts evaluate the NWR within the context of the larger ecoregion.

The HGM approach obtains and analyzes available historical and current information about: 1) geology and geomorphology; 2) soils; 3) topography and elevation; 4) hydrology and climate; 5) land cover and vegetation communities; 6) key plant and animal species; and 7) physical anthropogenic features of the CNWR and surrounding lands. Objectives for this HGM evaluation were:

1. Identify the Presettlement (pre-European contact) ecosystem conditions and the ecological processes supporting them at CNWR.
2. Evaluate changes in the CNWR ecosystem from the Presettlement period with specific reference to alterations in hydrology, topography, vegetation community structure and distribution, and resource availability for priority fish and wildlife species.
3. Identify restoration and management options plus ecological attributes needed to successfully restore and/or manage specific habitats and conditions at CNWR.

The Mud Lake basin, including CNWR, was formed by the complex succession of geologic processes throughout the Pleistocene and Holocene, including volcanism associated with the Yellowstone Hotspot, outwash from montane glaciers, the rise and fall of pluvial lakes, alluvial transport of sediments, and eolian processes. Alluvium from adjacent mountains and sediments transported by glacial, lacustrine, fluvial, and eolian processes created sedimentary interbeds and surface soils within volcanic basalts that contribute to confined and perched groundwater conditions that affect local groundwater movement and supply. Soils at CNWR range from somewhat excessively drained sands on lava plains to very poorly drained silty clays on relict lakebed features.

The climate at CNWR is semi-arid with annual precipitation averaging about 9 inches/year. Annual precipitation is highly variable, ranging from 43 to 171% of the mean. Snowpack in the headwaters of the Beaver-Camas subbasin is also highly variable, with annual peak snow water equivalent ranging from 9 to 31 inches. Historical water levels at CNWR peak during the spring as a result of snowmelt runoff and decline throughout the summer. In addition to seasonal patterns of flooding, CNWR and Mud Lake have evidence of long recurring 15-20 year patterns of peaks and lows in regional precipitation, runoff, and water levels, contributing to a relatively long wet-dry cycle of 30-40 years. Paleoclimate studies also suggest longer term multidecadal and centennial-scale variations in climatic conditions.

Historical vegetation communities at CNWR ranged from high desert sagebrush steppe uplands on sandy soils to herbaceous riparian meadows along Camas Creek and nearly permanently flooded wetlands at Sandhole Lake. The gradation of vegetation communities varied temporally and spatially depending on abiotic conditions and included open water/submerged aquatic vegetation, semi-permanently flooded robust emergent, seasonally flooded short emergent, wet and alkali meadows, salt desert shrub grasslands and sagebrush steppe with abundant native bunchgrasses. Wetlands at CNWR were maintained by spring runoff, poorly-drained silty clay soils deposited from pluvial Lake Terreton, the high water-holding capacity of the shallow Mud Lake alluvial aquifer, local precipitation, discharge from confined aquifers created by sedimentary interbeds, and the complex interaction of the regional ESRP and shallow alluvial aquifers. As a wetland oasis in the semi-arid ESRP, a rich diversity of animal species historically used the CNWR ecosystem. The abundance and productivity of vertebrate species was tied to seasonal and long-term patterns of water levels.

Extensive modifications to the hydrology of the ESRP began during the late-1800s when European settlers grazed sheep during the winter months and began to develop irrigation improvements for domestic livestock and ranching operations. Increased irrigation on the Egin Bench during the early-1900s coincided with one of the four wettest epochs in the western United States during the past 1,200 years. Both of these events contributed to the observed increase in the regional water table; but the relative proportional increase of each factor has not been modeled. Groundwater development in the ESRP increased rapidly during the 1950s and 1960s as agricultural crops and center pivot irrigation increased. As a result of groundwater pumping and more efficient surface water distribution, recharge to the regional aquifer started to decrease, lowering the water table by approximately 15 feet since the 1970s, and has resulted in a cumulative decrease in the ESRP aquifer storage of about 3%. Information on impacts to the shallow Mud Lake alluvial aquifer are limited, but early observations suggest that deepening and widening of ditches at CNWR for irrigation deliveries increased lateral subsurface drainage of water, thereby reducing the ability of the shallow aquifer to hold water and support wetland habitats.

Early water management at CNWR (and other refuges established during the 1930s) sought to "drought-proof" wetland areas and sustain waterfowl populations, resulting in extensive physical development and alterations to topography and water flow patterns. Refuge development actions in the late-1930s focused on improving existing infrastructure originally designed for irrigation and included cleaning and repairing ditches, rebuilding and extending dikes, and installing water-control structures. During the 1940s and 1950s development of water-control infrastructure for wetland habitats increased. Specifically, ditches, berms, and water-control structures were built or rehabilitated to: 1) maintain higher water levels in ponds; 2) move water to wetland impoundments that often dried before broods fledged; 3) allow for maximum diversion of Camas Creek water rights;

4) reduce flood damage; and 5) “keep Camas Creek in its channel.”

Management of more consistent, stable, and deepwater regimes since refuge establishment has ultimately compromised the long-term sustainability and productivity of the highly variable historical wetland system. More permanent and stable water regimes in wetland managed wetland units at CNWR gradually changed vegetation communities to more water tolerant species and increased the area of permanently flooded open water habitats. Diversion of water from Camas Creek reduced instream flows and overbank flooding into herbaceous riparian habitats. Water management since the early 1990s has incorporated periodic drawdowns, but areas of decadent robust emergent vegetation are still present. Altered sheetflow, fire suppression, and historical grazing have impacted sagebrush/bunchgrass steppe habitats. Upland and wetland vegetation communities also contain increasing amounts of invasive species.

Contemporary management should be based on understanding the historical and current regional context of the site relative to how, or if, the site provided dynamic resources. Refuge management should attempt to continue to provide key resources in naturally occurring times and distribution consistent with meeting life cycle requirements necessary to sustain native plant and animal populations. Recommendations in this HGM evaluation study are system-based first, with the goal of sustaining the ecosystem. These system-based recommendations are based on the assumption that if the integrity of the system is maintained and/or restored, that key resources for species of concern will be provided. This approach is consistent with recent recommendations to manage the NWR system to improve the ecological integrity and biodiversity of landscapes in which they sit.

Given constraints of surrounding land uses, mandates for restoring and managing ecosystem integrity, opportunities for within refuge and watershed scale conservation, and the HGM findings, we recommend that the future management of CNWR should consider the following goals:

1. Protect and restore the physical integrity and hydrologic processes of the shallow Mud Lake alluvial aquifer beneath CNWR and surrounding lands.
2. Restore natural topography and surface water flows, and where necessary manage flows to mimic natural hydrological conditions and maintain water rights.
3. Restore and/or manage for the diversity, composition, distribution, and regenerating mechanisms of diverse, self-sustaining native wetland and upland vegetation communities in relation to geomorphic landscape position.
4. Provide key resources that mimic natural patterns of resource availability and abundance, including plant and invertebrate food sources high in nutrients, appropriate structure and interspersion of vegetative cover, and refuge (e.g., areas of no or very low disturbance) for priority species during appropriate life history stages.

Specific recommendations to meet ecosystem restoration and management goals identified above are fully described in this report.

Future management of CNWR should include routine monitoring and management-oriented research to determine how ecosystem structure and function are changing, regardless of whether restoration and management options identified in this report are undertaken. Ultimately, the success in restoring and sustaining communities and ecosystem functions/values at CNWR will depend on how well the physical and hydrological integrity of the shallow alluvial Mud Lake aquifer is protected and how key ecological processes and events, especially naturally variable seasonal and annual flooding and groundwater flows, can be restored or mimicked by management actions. Many recommendations in this report will also increase the resiliency of CNWR by allowing it to better adapt to future climate change. Especially critical scientific information and monitoring needs for CNWR include:

1. Key baseline ecosystem data on detailed soil characteristics, hydrologic conditions of the shallow Mud Lake alluvial aquifer, submerged aquatic vegetation, and

habitat use in relation to local and regional habitat conditions;

2. Hydrological data on water use and flow patterns, water levels and duration of flooding within managed wetland units, soil moisture, and water quality; and

3. Long-term changes in plant and animal communities in response to management actions.

Adonia Henry

Cary Gardner

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Cary Gardner

INTRODUCTION

Camas National Wildlife Refuge (CNWR) is located in the Eastern Snake River Plain (ESRP) within the topographically closed Beaver-Camas subbasin of southeastern Idaho (Fig. 1). CNWR includes 10,578 acres of diverse wetland and upland habitats along eight miles of Camas Creek in Jefferson County, Idaho. Wetland habitats at CNWR historically were supplied by groundwater discharge, spring runoff and surface water from Camas, Beaver, and Warm creeks, and on-site precipitation. The amount and timing of surface water inputs depended on annually and seasonally dynamic snowpack in the nearby Centennial Mountains, local seasonal precipitation, and seasonal temperature and evapotranspiration patterns. Groundwater conditions in the regional ESRP and shallow Mud Lake alluvial aquifers were also important hydrologic drivers at CNWR.

CNWR was established as Camas Migratory Waterbird Refuge through Executive Order 7720 on October 12, 1937 with the primary purpose "as a refuge and breeding ground to migratory birds and other wildlife." The name of the refuge was changed when administration was transferred from the U.S. Department of Agriculture (USDA) to the U.S Fish and Wildlife Service (USFWS) in the Department of Interior. Since its establishment, management of CNWR has sought to manage water to maintain wetland habitats for breeding waterfowl. Surrounding land

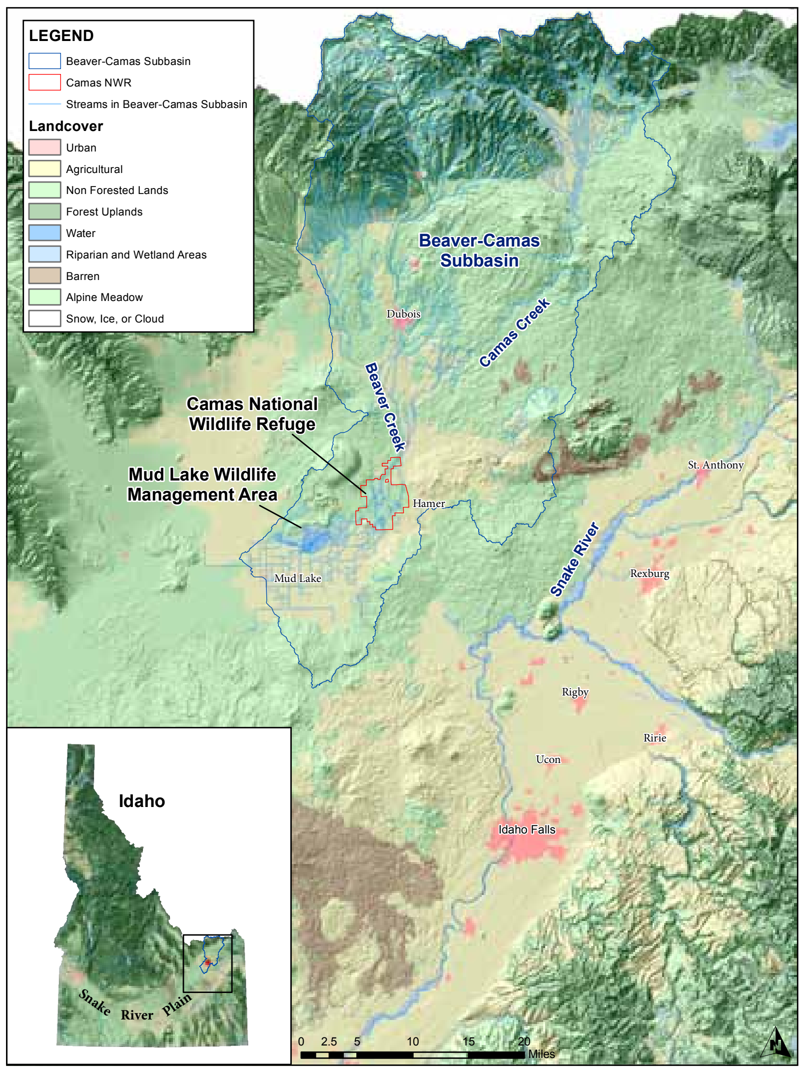

Figure 1. General location of Camas National Wildlife Refuge, Idaho. Landcover data from Idaho Gap Analysis Project (Landscape Dynamics Lab 1999) and hydrologic data from National Hydrography Dataset (USGS 2011).

uses have significantly altered the quantity of ground and surface water that reaches CNWR. Considerable water delivery and control infrastructure has been developed on the refuge to divert surface water and pump groundwater to manage 22 wetland units (USFWS 2012).

During 2010, the USFWS started a Comprehensive Conservation Plan (CCP) for CNWR. The draft CCP (USFWS 2014) articulates the long-term management direction for the refuge for the next 15 years; it is based on goals, objectives, and management strategies that consider the role of the refuge and its contribution to the regional landscape. Historical conditions (those prior to substantial human-related changes to the landscape) are often selected as the benchmark condition (Meretsky et al. 2006), but restoration to these historical conditions may not be well understood, feasible, or cost-effective, thereby compromising success of restoration actions. General USFWS policy (601 FW 3), under the Improvement Act of 1997, directs managers to assess not only historic conditions, but also "opportunities and limitations to maintaining and restoring" such conditions. Recently, Hydrogeomorphic Methodology (HGM) evaluation has been used to evaluate ecosystems on refuges and to assist ongoing CCP efforts (e.g., Heitmeyer and Fredrickson 2005, Heitmeyer and Westphall 2007, Heitmeyer et al. 2009, Heitmeyer et al. 2010, Heitmeyer et al. 2012). HGM evaluations identify restoration and management options following USFWS policies for NWRs (620 FW 1 and 601 FW 3) that "favor management that restores or mimics natural ecosystem processes or functions to achieve refuge purpose(s)."

This report details the HGM evaluation for CNWR and provides a historical context to understand the physical and biological formation, features, and ecological processes of lands within CNWR and the surrounding region. The HGM approach objectively seeks to understand: 1) how this ecosystem was created, 2) the fundamental physical and biological processes that historically "drove" and "sustained" the structure and functions of the system and its communities, and 3) what changes have occurred that have caused degradations and that might be reversed and restored to historical and functional conditions within a changing environment.

The HGM evaluation process is not species-based, but rather seeks to identify options to restore and maintain system-based processes, communities, and resources that ultimately will help support local and regional populations of native species, and other ecosystem functions, values, and services.

The HGM evaluation obtains and synthesizes available historical and current information about: 1) geology and geomorphology; 2) soils; 3) topography and elevation; 4) hydrology and climate; 5) land cover and vegetation communities; 6) key plant and animal species; and 7) physical anthropogenic features of the CNWR and surrounding lands.

Objectives for this report are:

1. Identify the Presettlement (pre-European contact) ecosystem conditions and the ecological processes supporting them at CNWR.

2. Evaluate changes in the CNWR ecosystem from the Presettlement period with specific reference to alterations in hydrology, topography, vegetation community structure and distribution, and resource availability for priority fish and wildlife species.

3. Identify restoration and management options plus ecological attributes needed to successfully restore and/or manage specific habitats and conditions at CNWR.

Historical data are most complete after 1900, when the region was already influenced by surface water diversions and irrigation throughout the ESRP, particularly at Egin Bench and along Camas and Beaver creeks (Stearns et al. 1939). When available, information from the 1880s and 1890s for the CNWR region and paleoclimate data are included to provide an understanding of the hydrologic character of the ESRP prior to European settlement.

Andy Vernon

THE HISTORICAL EASTERN SNAKE RIVER ECOSYSTEM

GEOLOGY, GEOHYDROLOGY, GEOMORPHOLOGY

Pre-Quaternary Volcanism

CNWR is located in the ESRP where it crosses through the Basin and Range province (Fig. 1). The ESRP was created as the North American tectonic plate drifted southwest over a hotspot in the earth's mantle that is currently under Yellowstone National Park. Volcanic activity began about 17 to 16 million years ago (Ma) during the Miocene Epoch of the Tertiary Period near southeastern Oregon and northern Nevada. Movement of the North American plate over the hotspot caused uplift and rhyolitic caldera eruptions followed by subsidence and basaltic volcanism (Phillips 2012).

Thrust-faulted mountains separated by narrow intermountain valleys of the Basin and Range structural province bound the southeast and northwest portions of the ESRP. These mountains consist of Precambrian through Mesozoic sedimentary rocks that were uplifted along normal faults during the late Tertiary and Quaternary (Kuntz et al. 1992). The east-west Centennial Mountains north of CNWR are a fault block that was elevated and tilted southward during the late Cenozoic. The western Centennial Mountains are composed primarily of sedimentary rocks of the Beaverhead Formation from the late Cretaceous and sandstone and shale from the Cretaceous (Witkind 1977, Alt and Hyndman 1986).

The origin of the volcanic progression of the Yellowstone hotspot is debated, but it is generally believed to be the trace of a mantle plume beginning just east of the Nevada-Oregon rift zone on the Oregon-Nevada border about 17 Ma (Pierce and Morgan 1992, Pierce et al. 2002). The rising and surfacing of basaltic melts at the McDermitt volcanic field from a large thermal mantle plume head coincided with widespread extension and normal faulting in the Basin and Range structural province. Pierce et al. (2002) suggest a causal relationship between these events resulting, in part, from the decreased ascension rate of the plume head when it came in contact with the North American plate that affected the lithosphere and asthenosphere under the active Basin and Range structural province. Significant uplift became the dominant factor in the Great Basin region about 17 Ma (Christiansen and Yeats 1992).

The direction, speed, and magmatism of the hotspot changed about 10 Ma near American Falls, Idaho. The movement of the North American plate shifted and slowed from approximately 2.8 to 1.1 inches/year. The previously large and active plume head began to stagnate and its "tail" or "chimney" penetrated through the plume head and spread radially outward at the base of the southwest moving lithosphere. This created the ESRP track of calderas and formed the nested v-shaped belts of active faults and uplift ahead and outward of the hot spot path (Pierce and Morgan 1992). Another characteristic of magmatism in the ESRP is the numerous small "monogenetic eruptive centers" that result from a relatively slow magma supply rate (Hughes et al. 1999). From 10 to 4 Ma, the volcanic fields were "flanked by Cordilleran fold-and-thrust belt terrain broken by late Cenozoic normal faults parallel to thrust belt structures" (Pierce and Morgan 1992:40). Rhyolite volcanic fields in the area of CNWR formed approximately 6.6 Ma during the late Miocene (Pierce and Morgan 1992).

As the ESRP was forming, Idaho's dry climate during the late Miocene and Pliocene resulted in sedimentary deposits that accumulated in valleys and on alluvial fans. Coarse sediments were located around the valley edges and alluvial fans, including alluvial fans at the base of the Centennial Mountains that slope toward Mud Lake. Finer sands and silts traveled farther and accumulated in the valleys. These Tertiary volcanic and sedimentary deposits of the ESRP are underlain by Paleozoic sediments, approximately 2 to 4 miles thick on top of the granitic crust that extends to approximately 25 miles below the surface (Braile et al. 1982, Sparlin et al. 1982, Peng and Humphreys 1998). Little is known about the pre-Tertiary rocks that are below the more recent volcanic rocks of the ESRP. Pre-Tertiary rocks described from the surrounding mountains that probably underlie the Tertiary formations in the Mud Lake area are cemented and nearly impermeable and therefore essentially form a "watertight basement" (Stearns et al. 1939). These pre-Tertiary rocks also enclose the Mud Lake region on three sides. Therefore, groundwater leaves the Mud Lake region "underground only along its southern border where the old rocks do not rise to altitudes sufficiently great to cut off the escape" (Stearns et al. 1939:42). Pre-Tertiary rocks have been folded and locally faulted and overthrust during several periods of deformation, but late Tertiary and Quaternary rocks conceal the structure of the earlier rocks.

A basaltic sill-like body resulting from the magmatic activity of the Yellowstone hotspot that injected basaltic melt into the crust occupies the lower portion of the granitic upper crust from approximately 6 to 12 miles below the surface (Peng and Humphreys 1998). The lower crust has a low-velocity zone at its base, presumed to be partially molten crust located above the mantle tapering in thickness as you move southwest of the Yellowstone area due to cooling and lower crustal flow (Priestly and Orcutt 1982, Peng and Humphreys 1998). Based on the crustal structure, Braile et al. (1982:2669) suggests that the ESRP formed during an intensive period of "intrusion of mantle-derived basaltic magma into the upper crust generating explosive silicic volcanism and associated regional uplift and caldera collapse."

Quaternary Processes, Geohydrology, and Geomorphology

Hughes et al. (1999:147) describes the surficial volcanic stratigraphy of the ESRP as a "complex Quaternary–Holocene succession that includes small coalescent shields, tuff rings and cones, evolved eruptive centers with composite cones, rhyolite domes, and sedimentary interbeds." Volcanism, outwash from montane glaciers, the rise and fall of glacial lakes, fluvial transport of sediments, and eolian processes during the Pleistocene created this complex stratigraphy that defines the geohydrologic and geomorphic conditions of the ESRP.

Coalesced shield volcanoes and tube-fed lava cones comprise more than 95% of the total volume of basalt in the ESRP; eruptive-fissure deposits, tephra cones, and deposits of hydrovolcanic eruptions make up the remainder (Kuntz et al. 1992). Most surface basalt lava flows formed less than 730 thousand years ago (ka) and the lava flow and sediment sequence is about 0.6 to 1.2 miles thick throughout most of the ESRP (Kuntz et al. 1992). Basalt and other rocks younger than the rhyolite have only minor and local deformation. Large quantities of rhyolite lava flows, ignimbrites, and pyroclastic deposits from early volcanic activity underlie surface basaltic lava flows throughout the ESRP (Alt and Hyndman 1989, Kuntz et al. 1992, Spinazola 1994a).

A cluster of large shield volcanoes, lava flows, and rhyolitic domes form a northeast-trending axial volcanic zone creating a topographically high central axis of the ESRP, often referred to as the "axial volcanic high" (Hughes et al. 1999, Phillips 2012). This axial volcanic high divides the ESRP into north and south segments, which differ in structure and geomorphology (Phillips 2012). The Mud Lake region and other drainages north of the axial volcanic high do not have a direct surface water outlet to the Snake River. An east-west line of vents south of Mud Lake, referred to as the Circular Butte-Kettle Butte rift zone, forms the southern boundary of the Mud Lake basin, preventing surface water drainage from Medicine Lodge, Beaver, and Camas creeks from reaching the Snake River.

Volcanic rift zones in the ESRP contain numerous volcanic structures and landforms where volcanic activity occurred over tens or hundreds of thousands of years with similar repose intervals. The Spencer-High Point volcanic rift zone, located north of CNWR, contains numerous geologically young feeder fissures for tephra cones, ramparts, and small shield volcanoes, a few open fissures, feeder fissures for basalt vents, grabens, and faults (Kuntz et al. 1992). As with other rift zones in the ESRP, the Spencer-High Point volcanic rift zone is collinear with a basin and range fault. Kuntz et al. (1992:247) suggests that volcanic rift zones in the

ESRP result from regional extensional tectonics of Basin and Range faulting that leads to greater amounts of magma production in the lithosperic mantle creating "long-lived, self perpetuating zones of volcanism." As one of the youngest sites of volcanism in the ESRP (some lava fields are <15 ka), the Spencer-High Point rift zone is associated with major Quaternary faulting of the Middle Creek Butte fault along the southwest margin of the Centennial Mountains. In addition, the Spencer-High Point rift zone crosses the northern portion of the underlying rhyolitic Kilgore Caldera (4.3 Ma), where fracture pathways for magma ascent are more abundant compared to rift zones that do not cross calderas (Kuntz et al. 1992).

Quaternary basalt flows are interbedded with sediments that contribute to confined ground water conditions and affect local groundwater movement and supply (Spinazola 1994a). Alluvium from adjacent mountains and sediments transported by glacial, lacustrine, fluvial, and eolian processes throughout the Quaternary created sedimentary interbeds within the basalts, but little is known about the distribution and mineralogy of these sedimentary deposits (Lindholm 1996).

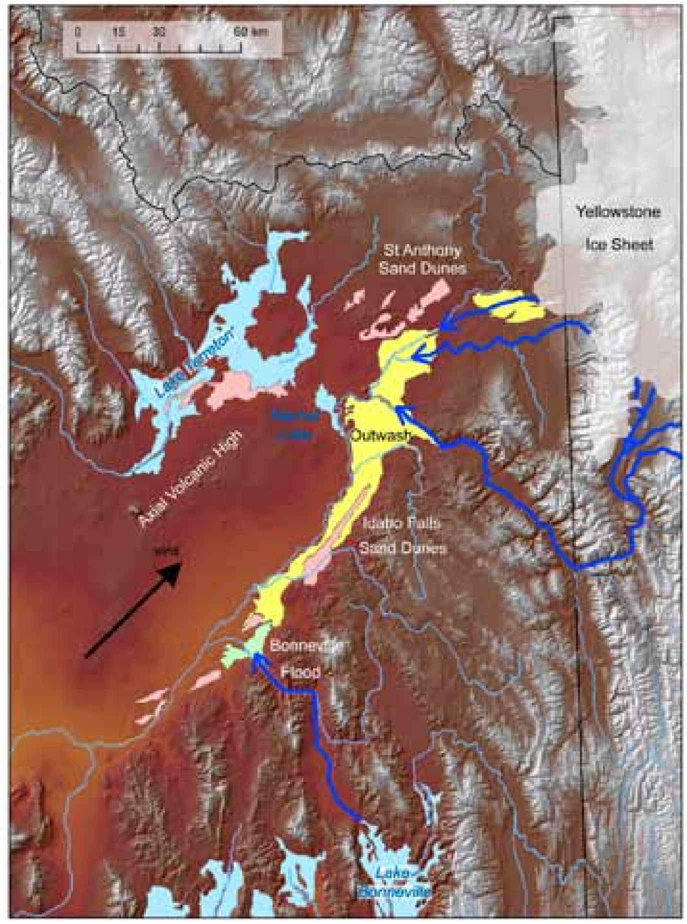

Figure 2. The Eastern Snake River Plain approximately 25-14 thousand years ago during the late Pleistocene Pinedale glaciation. Position of the Yellowstone ice sheet after Licciardi and Pierce (2008). Map from Phillips (2012).

Two ice ages are clearly evident on Idaho's landscape; the Illinoian (or Bull Lake) glaciation occurred about 140 to 150 ka and the Wisconsin (or Pinedale) glaciation occurred between 14 and 25 ka. Glacial ice from the Wisconsin never formed on the Snake River Plain, but mountains north and south of the ESRP were glaciated and a large ice sheet formed several times on the Yellowstone Plateau. Steep glacial cirques on the headwater tributaries of Camas Creek are highly visible (Stearns et al. 1939).

Shallow lakes, including pluvial Lake Terreton in the northeastern portion of the ESRP, formed in areas of internal drainage during glacial periods. Lake Terreton exceeded 140 square miles at its maximum extent and can be traced from Howe to Menan (Fig. 2) (Stearns et al. 1939, Helm-Clark and Link 2006, Phillips 2012). High stands of Lake Terreton occurred approximately160-120 ka, 100-80 ka, 22-11 ka, and < 1 ka associated with long-term glacial-interglacial periods and shorter-term climate changes (Gianniny et al. 2002).

Lake Terreton includes two subbasins, Big Lost Trough and Mud Lake. The Big Lost Trough subbasin is north of the Arco volcanic zone and south of the Circular Butte-Kettle Butte rift zone. The Mud Lake subbasin, which includes CNWR, occupies the depression created by the axial volcanic high and the Circular Butte-Kettle Butte rift zone south of Mud Lake. Under current conditions, Big Lost Trough is a recharge basin and Mud Lake is a discharge basin. Despite this difference, large-scale sedimentation processes that were primarily controlled by climate are likely similar; therefore, results from the more intensively studied Big Lost Trough are included and compared to Mud Lake, when possible.

Sedimentary interbeds in the Big Lost Trough include lacustrine, eolian, and fluvial deposits with similar mineralogy as surficial sediments (Mark and Thackray 2002). When water levels of Lake Terreton rose, the subbasins filled with fine grained sediments, primarily silty clay in the Big Lost Trough subbasin (Stearns et al. 1939, Mark and Thackray 2002). The lakebed sediments in Mud Lake subbasin may have even higher clay content or may have thicker clay deposits. Stearns et al. (1939) described the lakebed sediments in the vicinity of Mud Lake as “so clayey… [that] there is little downward percolation through them.” These extensive layers of fine-grained lake bottom sediments affected ground water movement by creating locally confined conditions with artesian springs where water “leaked” through the confining sediments and supporting a perched water table in the vicinity of Mud Lake (Stearns et al. 1939).

Alluvial fan deposits also increased during glacial periods, bringing coarse to fine grained sediment onto the ESRP (Stearns et al. 1939, Mark and Thackray 2002). Alluvial deposits in the Big Lost Trough subbasin indicate the former existence of aggrading braid-plains during glacial periods (Mark and Thackray 2002). Lacustrine sediments in the Mud Lake subbasin interfinger with coarse grained alluvial deposits of ancient deltas of Medicine Lodge, Beaver, and Camas creeks to the north. Extensive deposits of alluvium, mostly in the form of broad, coalescing alluvial fans, border the foothills on the outskirts of the Mud Lake region (Stearns et al. 1939). Eolian and fluvial processes during interglacial periods increased sediment complexity as lacustrine and fluvial sediments were re-distributed (Stearns et al. 1939, Mark and Thackray 2002). Playas and dunes developed during interglacial periods.

As a result of climate-driven sedimentary processes, the thickness and distribution of subsurface clay sediments in the Mud Lake and Big Lost Trough region is variable (Figs. 3, 4) (Spinazola 1994b). Clay sediments are thicker beneath the current day Mud Lake than they are under Camas Creek in the northern portion of CNWR. Alluvial deposits of sand and gravel are present beneath clay deposits along Camas Creek in the northern portion of CNWR. The thickness of clay deposits in the southern portion of CNWR is not mapped, but is likely intermediary between those at Mud Lake and those further upstream. The hydrologic conductivity of sedimentary interbeds greatly affects groundwater movement. Although particle size is a major determinant of hydrologic conductivity, sorting, packing, porosity, particle shape, and fracture flow also affect hydrologic conductivity (Mark and Thackray 2002). For clay interbeds, structure, carbonate buildup, swelling, and particle charge are likely important factors in determining hydraulic conductivity (Mark and Thackray 2002).

The surficial geology at CNWR is dominated by Quaternary colluvium loess with late Pleistocene tholeiite lava flows along the western edge of the refuge (Fig. 5) (Bond et al. 1978). Loess is widespread across the ESRP. North of the axial volcanic high loess originated from alluvial fans and outwash from drainages with alpine glaciers (Phillips

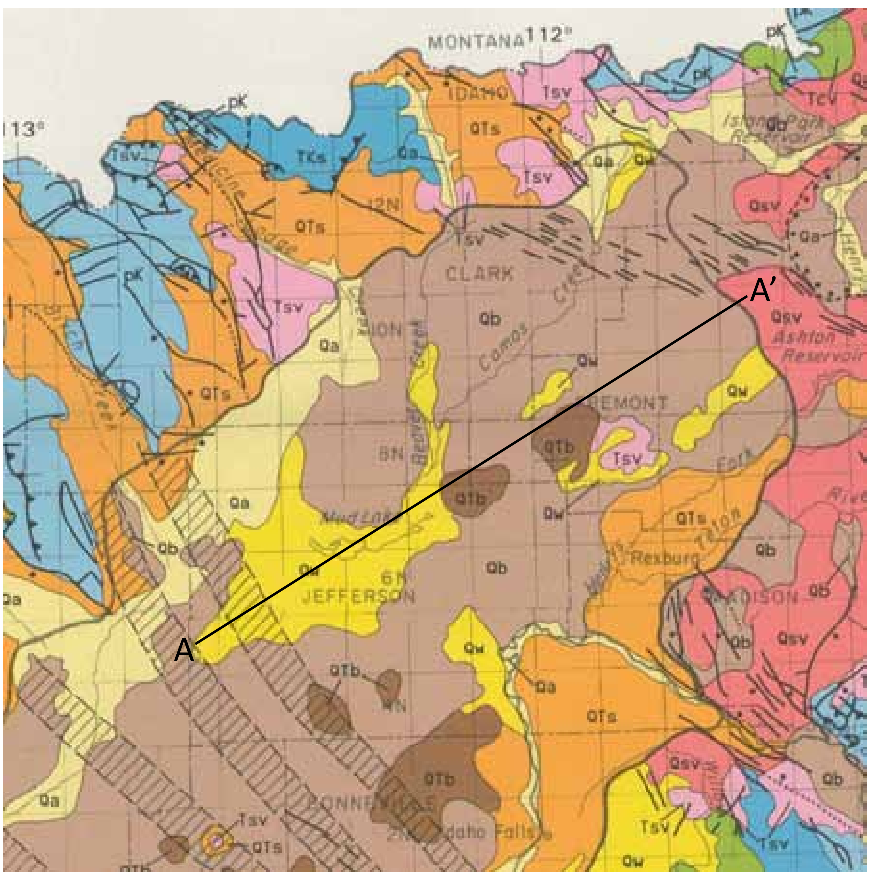

Figure 3. Generalized geologic map of the Eastern Snake River Plain near Mud Lake and Camas National Wildlife Refuge. Qa=Holocene alluvium; Qw=Holocene windblown deposits (includes lake and glacial flood deposits); Qb=Holocene Olivine basalt; Qsv=Pleistocene silicic volcanic rocks (Ryholitic); QTb=older basalt (Pliocene and Miocene); QTs=older alluvium (Pleistocene, Pliocene, & Miocene); Tsv=Older silicic volcanic rock (Pliocene to Miocene). Modified from Whitehead (1992). Cross section A-A’ is described in Figure 4.

2012). In the Idaho Falls area, loess dated at 16 to 25 ka accumulated at a rate of about 2 feet/ka (Phillips 2012). Following the retreat the Yellowstone ice sheet and other local glaciers, stream outwash and alluvial fan discharge was reduced, resulting in diminished loess accumulation (Phillips 2012). Sand dunes in the ESRP formed during the Holocene after loess deposition stopped. Regional droughts controlled periods of dune destabilization and movement (Phillips 2012). Sand dunes in the vicinity of Juniper Buttes migrated from the vicinity of Mud Lake and were derived from the lake deposits typically developed near Terreton and the sinks farther west (Stearns et al. 1939)

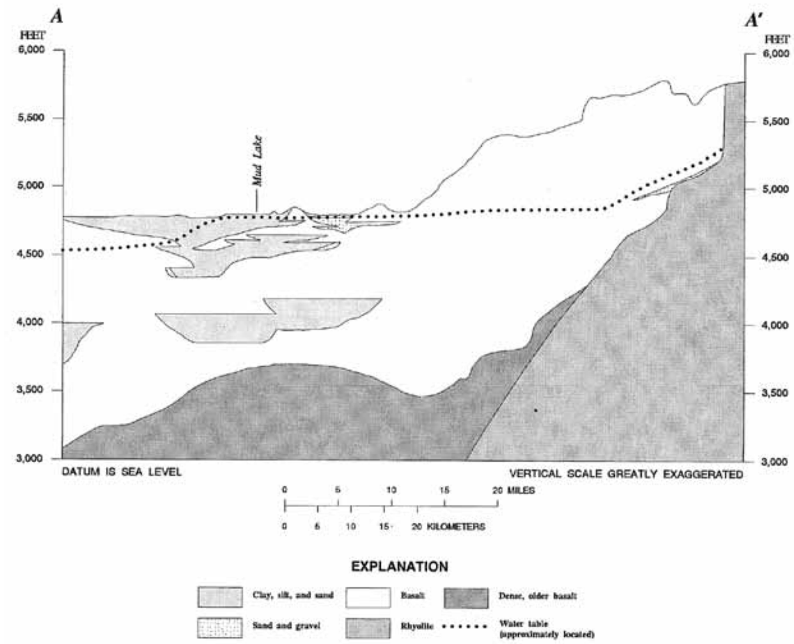

Figure 4. Generalized geologic cross section of A–A' (see Figure 3 for cross section location). From Spinazola (1994b).

Well logs at the refuge are indicative of the volcanic activity followed by periods of sedimentary deposition. For example, the well log for well #8 shows sedimentary deposits of sand, gravel, and clay down to 74 feet below the surface. Basalt lava occurs from 74 to approximately 239 feet below the surface (bottom of the well). Sedimentary deposits are not uniform among wells, supporting the heterogeneous distribution of sedimentary deposits from eolian, fluvial, alluvial, and lacustrine deposits.

SOILS

Soil data for CNWR include the Jefferson County soil survey completed during 1971-1974 (Soil Conservation Service 1979), which is available through Natural Resources Conservation Service (NRCS) Web Soil Survey (NRCS 2008, 2012), and well log data from the refuge files. In addition to vertical heterogeneity of the soil profiles documented from well logs, surface soil features are spatially heterogeneous and diverse ranging from very poorly-drained Fluvaquents to somewhat excessively drained Grassy Butte loamy sand (Table 1, NRCS 2008). The natural drainage class of soils is defined as the frequency and duration of wet periods similar to the conditions under which the soil developed and is closely tied to the growth of mesophytic crops (Soil Survey Division Staff 1993, Sprecher 2001).

Twenty-three different soil classifications occur within CNWR (Fig. 6). The following four soil types occurring on relict lakebeds cover approximately 60% of CNWR: Grassy Butte-Medano, Levelton-Medano, and Medano-Psammaquents complexes and Fluvaquents. Ten other soil types also occur on relict lakebeds while six soil classifications are located on lava plains. Characteristics of these soil types are summarized from NRCS (2008, 2012) (Table 1).

The Grassy Butte-Medano complex occurs on 21% of CNWR. Within this soil complex, the somewhat excessively drained Grassy Butte loamy sands (60% of map unit) are eolian deposited dunes on relict lakebeds. The poorly drained Medano loamy sands (20% of map unit) are mixed alluvium and/or lacustrine deposits located in depressions within relict lakebeds. This soil complex also contains a small amount of Psammaquents (5% of map unit) formed from mixed alluvium in depression on relict lakebeds.

Fluvaquents are the next most abundant soil type occurring on 17% of CNWR. Silty clay and stratified silty clay to silt loam profiles of Fluvaquents are very poorly drained soils that are very slightly saline to strongly saline. This soil type also contains a small amount of Psammaquents (10% of map unit).

The Levelton-Medano complex occurs on 12% of CNWR. Within this soil complex poorly drained Levelton soils (45% of map unit) are characterized by silty clay and clay loam down to 39 inches, below which it is stratified sandy loam to silty clay. These lacustrine

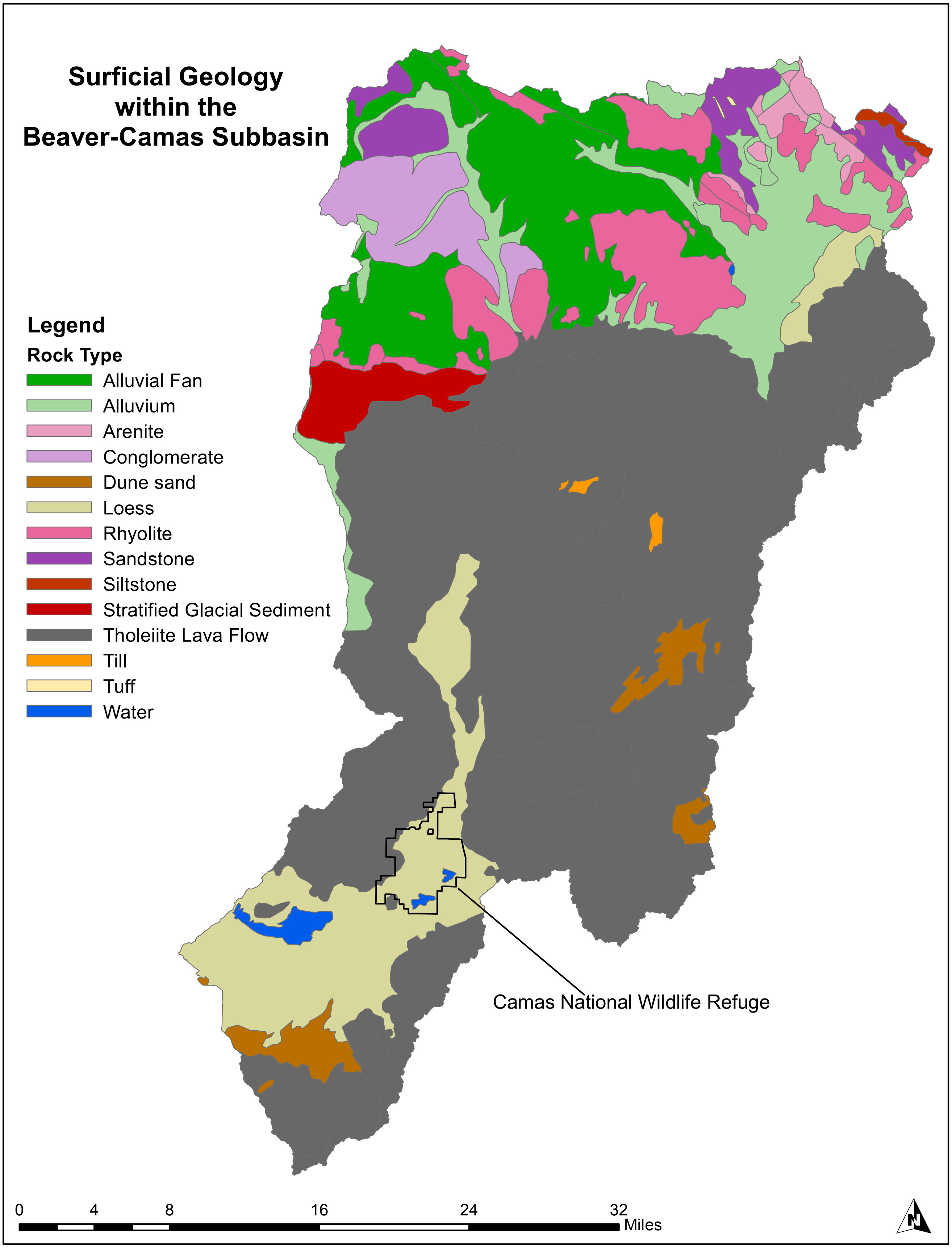

Figure 5. Surficial geology within the Beaver-Camas subbasin. From Bond et al. (1978).

Table 1. Soil characteristics at Camas National Wildlife Refuge. Data compiled from NRCS (2008).

Unit	Soil type	Landform	Parent Material	Slope	Drainage Class	Capacity to Transmit Water	Depth to water table	Available Water Capacity	pH	Salinity (mmhos/cm)	Sodium Absorption Ratio
24	Diston loamy sand	Lava plains	Eolian deposits	0-4%	Somewhat excessive	Very low to moderately low	> 80 in.	Very low (2.2 in)	7.9-8.4	0	0
29	Fluvaquents	Relict lakebeds	Lacustrine deposits	nearly level	Very poor	Very low to moderately high	0	Low (3.2 in)	7.9-9.0	4-32	5-13
30,31	Grassy Butte sand	Lava plains	Eolian deposits	2-4% 2-20%	Somewhat excessive	High to very high	> 80 in.	Low (4.1 in)	6.6-8.4	0	0-8
32,34	Grassy Butte loamy sand	Lava plains	Eolian deposits	2-4% 2-20%	Somewhat excessive	High to very high	> 80 in.	Low (4.2 in)	6.6-8.4	0	0-8
36	Grassy Butte-Medano Complex										
	Grassy Butte: 60%	Dunes on relict lakebeds	Eolian deposits	0-4%	Somewhat excessive	High to very high	> 80 in.	Low (4.1 in)	6.6-8.4	0	0-8
	Medano: 20%	Depressions on relict lakebeds	Mixed alluvium and/or lacustrine deposits	0-3%	Poor	High	12-36 in	Low (5.1 in)	4.5-5.5	0	0
37	Grassy Butte-Rock outcrop complex										
	Grassy Butte, very stoney surface: 30%	Lava plains	Eolian deposits	2-20%	Somewhat excessive	High to very high	> 80 in.	Low (4.1 in)	6.6-8.4	0	0-8
	Rock outcrop: 20%	Bedrock	Bedrock	2-20%	n/a	n/a	n/a	n/a	n/a	n/a	n/a
54	Levelton loamy sand	Depressions on lakebeds	Lacustrine deposits	0-1%	Poor	Moderately low to moderately high	12-24 in	High (9.2 in)	4.5-5.5	0	0
56	Levelton loam, drained, moderately saline-alkali	Relict lakebeds	Lacustrine deposits	0-1%	Poor	Moderately low to moderately high	12-36 in	High (9.9 in)	4.5-5.5	0	0
60	Levelton-Medano complex										
	Levelton: 45%	Relict lakebeds	Lacustrine deposits	0-1%	Poor	Moderately low to moderately high	12-24 in	High (9.2 in)	4.5-5.5	0	0
	Medano: 30%			0-1%	Poor	High	12-36 in	Low (5.1 in)	4.5-5.5	0	0
70	Matheson loamy sand	Lava plains	Mixed alluvium and/or eolian deposits	2-8%	Well	High	> 80 in.	Moderate (6.7 in)	7.4-8.4	0-2	0-5
73	Matheson sandy loam	Lava plains	Mixed alluvium and/or eolian deposits	4-8%	Well	High	> 80 in.	Moderate (7.2 in)	7.4-8.4	0-2	0-5
81	Medano complex	Relict lakebeds	Mixed alluvium and/or eolian deposits	0-2%	Poor	High	12-36 in	Low (5.1 in)	4.5-5.5	0	0
82	Medano-Psammaquents complex										
	Medano: 80%	Relict lakebeds	Mixed alluvium and/or eolian deposits	0-2%	Poor	High	12-36 in	Low (5.1 in)	4.5-5.5	0	0
	Psammaquents: 15%	Depressions on relict lakebeds	Mixed alluvium	0-2%	Very poor	High to very high	0-6 in.	Low (4.4 in)	6.6-7.8	0	0
93	Montlid-Heiseton complex										
	Montlid, very stoney surface: 65%	Playas on relict lakebeds	Lacustrine deposits	0-1%	Moderately well	Moderately high	24-48 in.	High (11.7 in)	7.9-8.4	0-2	5-13
	Heiseton, very stoney surface: 15%	Hillslopes, relict lakebeds	Mixed alluvium	0-4%	Moderately well	High	48-72 in	Low (4.9 in)	7.9-8.4	0-2	0-5
104	Rock outcrop-Bondfarm complex										
	Rock outcrop: 40%	Bedrock	Bedrock	2-6%	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Bondfarm: 30%	Relict lakebeds, lava plains	Eolian deposits over bedrock from basalt	2-6%	Well	High	> 80 in.	Very low (2.2 in)	7.9-8.4	0	0
107	Terreton loamy sand	Relict lakebeds	Lacustrine deposits	0-1%	Well	Moderately low to moderately high	> 80 in.	High (10.2 in)	7.9-8.4	0-2	0-5
108	Terreton sandy loam	Relict lakebeds	Lacustrine deposits	0-1%	Well	Moderately low to moderately high	> 80 in.	High (10.2 in)	7.9-8.4	0-2	0-5
110	Terreton sandy clay loam	Relict lakebeds	Lacustrine deposits	2-4%	Well	Moderately low to moderately high	> 80 in.	High (10.2 in)	7.9-8.4	0-2	0-5
126	Zwiefel fine sand	Relict lakebeds	Eolian deposits and/or lacustrine deposits	0-2%	Well	Moderately low to moderately high	> 80 in.	Very low (2.3 in)	7.9-8.4	0	0-8
127	Zwiefel fine sand			2-4%	Well	Moderately low to moderately high	> 80 in.	Very low (2.3 in)	7.9-8.4	0	0-8
128	Zweifel loamy sand	Relict lakebeds	Eolian deposits and/or lacustrine deposits	0-2%	Well	Moderately low to moderately high	> 80 in.	Very low (2.3 in)	7.9-8.4	0	0-8

sediments were deposited on relict lakebeds. Other components of this soil complex include Medano (30%), and small amounts (≤ 5% each) of Hoovey clay, Zwiefel sand, and Psammaquents.

The fourth most abundant soil type is the Medano-Psammaquents complex that occurs on 10% of CNWR. Medano, described above, compromises 80% of the map unit and Psammaquents comprise 20% of the map unit. Psammaquents are very poorly drained soils from mixed alluvium that occur in depressions on relict lakebeds. Grassy Butte loamy sand and Levelton clay loam occur in small amounts (< 5% each) in this soil complex.

Other soil types comprising < 10% of CNWR include Grassy Butte loamy sand (8%) and the Medano complex (7%). Six percent of CNWR was classified as water during the 1979 soil survey. All other soil types each comprise < 5% of CNWR. Sand dunes near Camas and Hamer were often 2 to 10 feet high and supported considerable vegetation (Stearns et al. 1939).

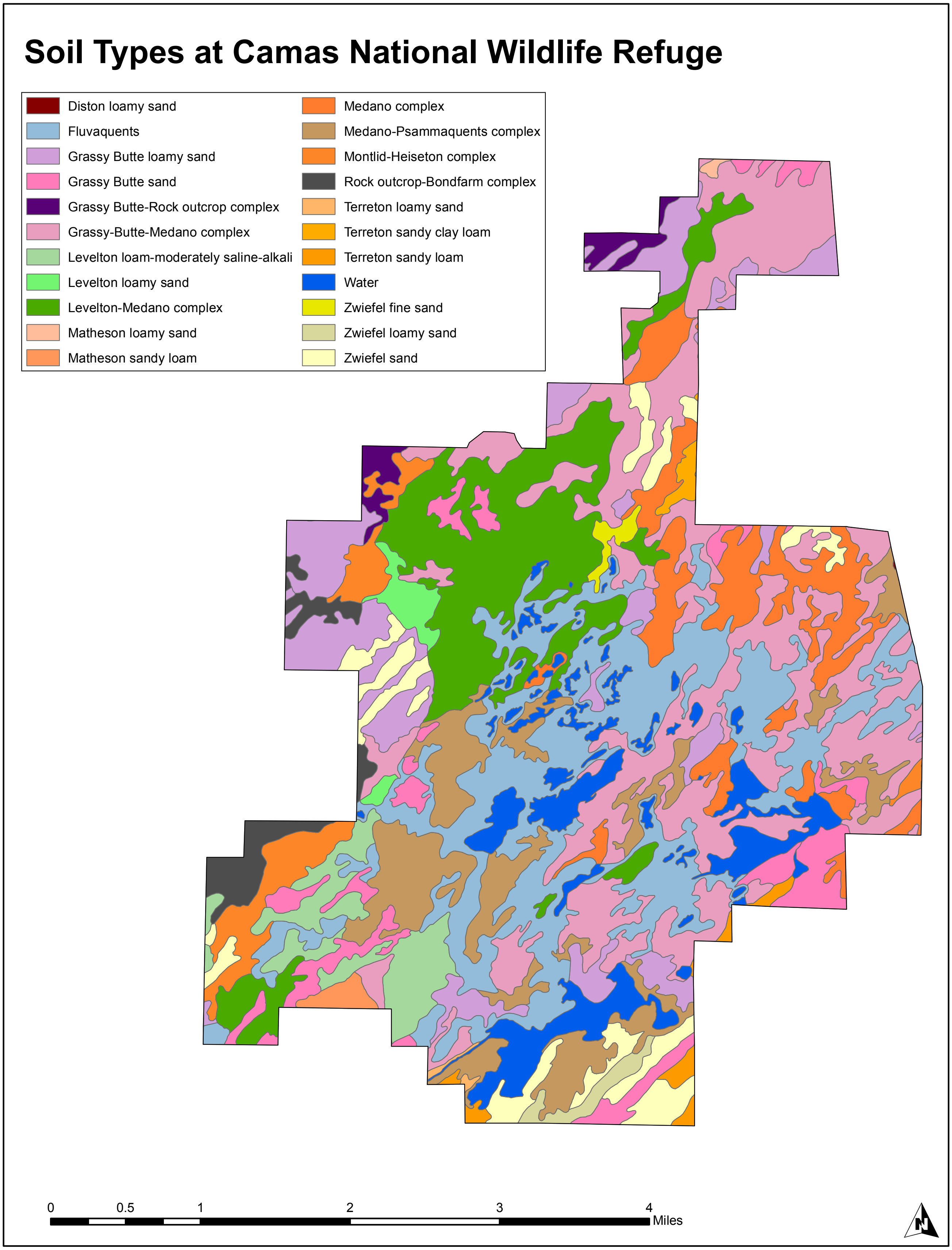

Figure 6. Soil types at Camas National Wildlife Refuge, Idaho. From NRCS (2008, 2012) based on Soil Conservation Service (1979).

TOPOGRAPHY

Earliest available elevation data is from a topographic base map dated 1943 with survey data collected during 1937 (Fig. 7). Light Detection and Ranging (LiDAR) topographic surveys of the refuge and surrounding lands were flown during fall 2011 (Fig. 8). Based on LiDAR data, elevations at CNWR range from approximately 4,780 feet above mean sea level (amsl) at Rays Lake to 4,850 feet amsl along the western boundary. Sagebrush steppe and desert shrub habitats on the west side of the refuge range from 4,796 to 4,850 feet amsl. In general, wetland elevations decrease from the north to south end of CNWR. Most wetland areas within the southern portion of the refuge are < 4, 790 feet amsl. Wetlands at the north end of the refuge occur at > 4,800 feet amsl.

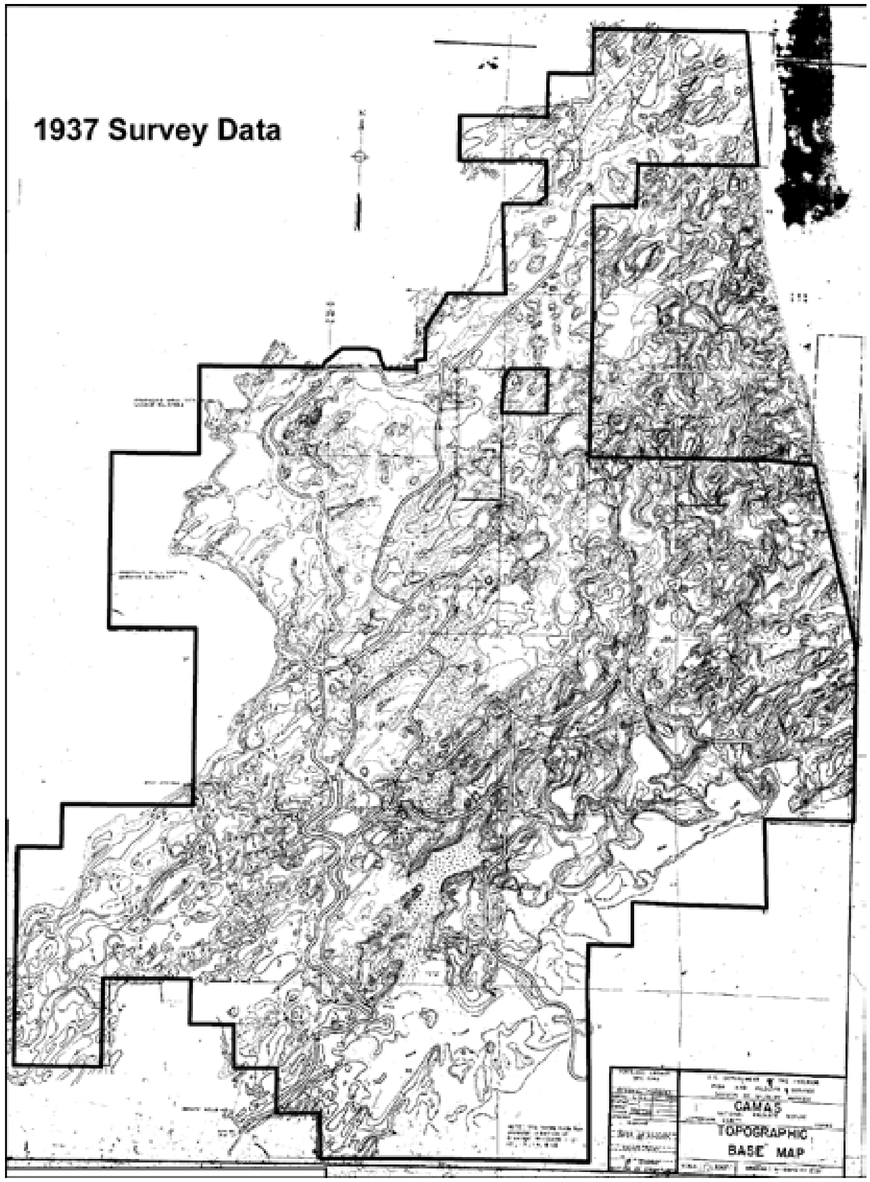

Figure 7. Topographic base map of Camas National Wildlife Refuge dated 1943 and based on 1937 survey data.

CLIMATE AND HYDROLOGY

Climate

Historical climate data from individual stations near CNWR are sporadic; these include the Camas Station 101395 (1908-1922), Mud Lake Station 106221 (1912-1948), and Hamer Station 103964 (1948-2012). Long-term climate data from the U.S. Historical Climatology Network (USHCN) (Menne et al. 2012) are available for the Aberdeen Station 10010 (1895-2011), which is approximately 75 miles southwest of CNWR in the ESRP. Average annual precipitation at Aberdeen, Idaho from 1971-2000 (9.25 inches/year) is similar to average precipitation at CNWR (9.81 inches/year) based on Parameter-elevation Regressions on Independent Slopes Model (PRISM) (Daly 2002; Daly et al. 2008). Therefore, data from Aberdeen are used as representative of climatic conditions at CNWR because trends in precipitation and temperature are likely similar.

Long-term mean annual precipitation for the water year (Oct. 1 – Sept. 30) at Aberdeen is 8.8 inches/year and ranges from 43 to 171% of the mean (Fig. 9). Extremes in precipitation appear to have increased since the late-1980s with the lowest precipitation on record occurring during 1988 (3.86 inches) and 1992 (3.82 in) and the highest precipitation occurring during 1993 (14.57 inches) and 1995 (15.1 inches). Precipitation at Hamer is fairly constant throughout the year, with average monthly total precipitation generally between 0.5 and 0.75 inches except during May and June when it is approximately 1.25 inches (Fig. 10) (Western Regional Climate Center 2013).

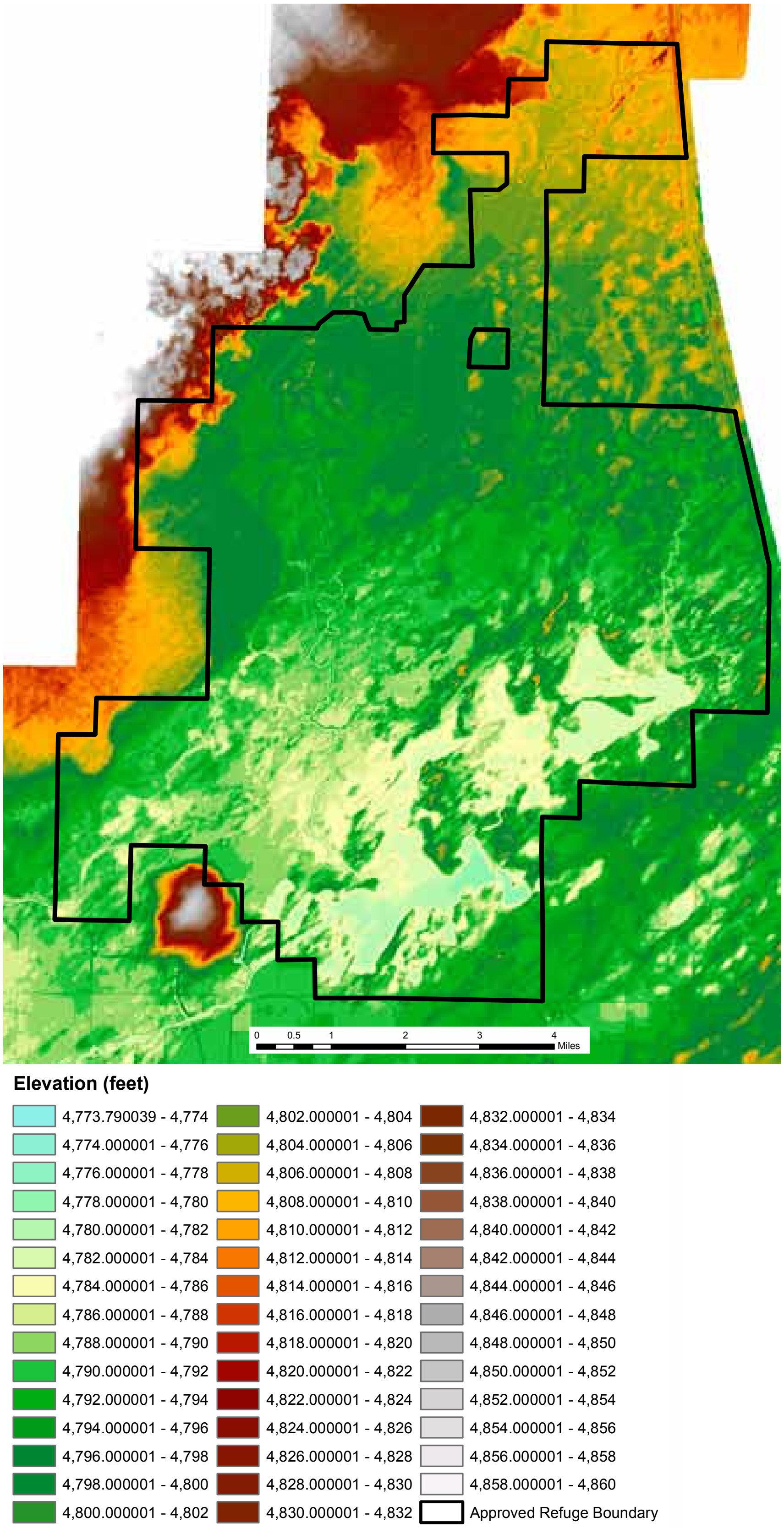

Figure 8. LiDAR bare earth elevations (flown during fall 2011) for Camas National Wildlife Refuge and the Mud Lake area, Idaho. (USFWS)

Average daily high temperatures range from about 90 °F during summer (often exceeding 100 °F) to 30 °F during winter. Average daily low temperatures range from 50 °F during summer to just above 0 °F during winter (Fig. 11) (Western Regional Climate Center 2013). Hot, dry summers result in relatively high evaporation rates on the ESRP, ranging from 40 to 55 inches/year, 80% of which occurs from May to October (Goodell 1988). Evaporation estimates at Mud Lake were about 36 inches/year (Stearns et al. 1939).

No long-term data from USHCN are available for the Centennial Mountains. However, the Crab Creek SNOTEL Station 424 is located near a tributary of West Camas Creek in the Centennial Mountains and has been in operation since 1979 (NRCS 2013b). The snow water equivalent (SWE) at Crab Creek usually peaks during late March or early April. For the period of record, annual peak SWE has ranged from 31.1 (April 1983) to 8.8 inches (March 1987 and 2007) (Fig. 12).

The Palmer Drought Hydrological Index (PDHI) is a long-term cumulative hydrological index used to quantity the hydrological impacts of drought (e.g., reservoir levels, groundwater levels, etc.) that generally take longer to develop and recover from. During the 20th century, wet/dry cycles occurred at relatively long intervals with an 18-year wet period from 1906 to 1923 and a 25-year wet period from 1962 to 1986. Two 15-year drought periods during 1924-1961 were separated by a 9-year wet period. Relatively short (< 8 years) wet/dry cycles have occurred from 1987 to present (Fig. 13) (NOAA 2013).

Reconstruction of paleoclimate conditions in the western United

States indicate that wet and dry periods have fluctuated on interannual, decadal, multidecadal, and centennial-scale time periods throughout the Holocene (e.g., Cook et al. 2004, Pederson et al. 2006, Cook et al 2007). The western United States experienced long periods of intense drought during warmer and drier conditions from 900 to 1300 (Medieval Warm Period) followed by wetter and cooler conditions during the Little Ice Age (1400-1700), 1829, and 1915 (Cook et al. 2004).

Climatic conditions in southeast Idaho during the early 19th century include periods of drought during 1805-1806 and 1818-1820 (Cook et al. 2007), followed by one of the four wettest epochs in the western United States since 800 (Cook et al. 2004). After the wet period of 1829, the climate in the western United States transitioned back into a period of drought by the 1850s. During the late-1800s, above average wetness occurred in the eastern Idaho during 1867-1869 and 1876-1878, followed by drought throughout the western United States and Great Plains during the 1880s and 1890s (Cooke et al. 2007). Wet conditions returned during the early-1900s with 1915 as the mid-point of another of the four wettest epochs in the past 1,200 years.

Recent climate change patterns for the U.S. Rocky Mountains and Upper Columbia River Basin during the 20th century summarized by McWethy et al. (2010) indicate: 1) increased temperatures in most areas of 0.9 to 3.6 °F; 2) annual rates of temperature increase in the northern Rocky Mountains that are two to three times the global average; 3) increasing night time minimum temperatures; 4) variable trends in precipitation; 5) significant declines in snowpack; and 6) earlier snowmelt and peak runoff and associated decreases in summer stream flows.

The trend in decreasing SWE of 1 April snowpack throughout the western United States is primarily related to increases in temperature and

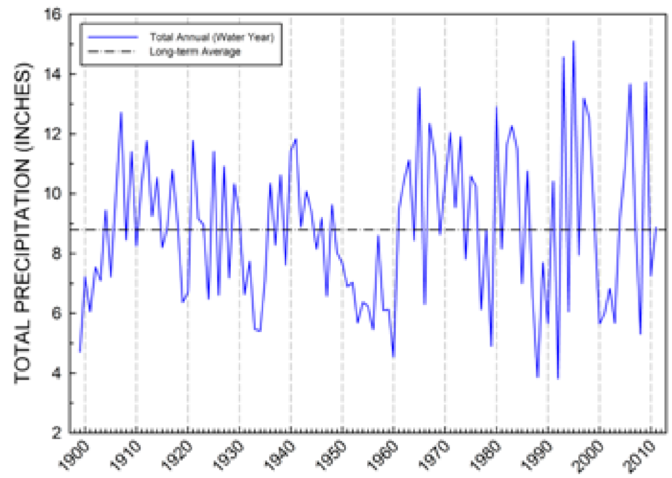

Figure 9. Water year (October 1 – September 30) total annual precipitation at Aberdeen, Idaho (Climate Station 100010), approximately 75 miles southwest of Camas National Wildlife Refuge from 1899 to 2011. Data compiled from Menne et al. (2012).

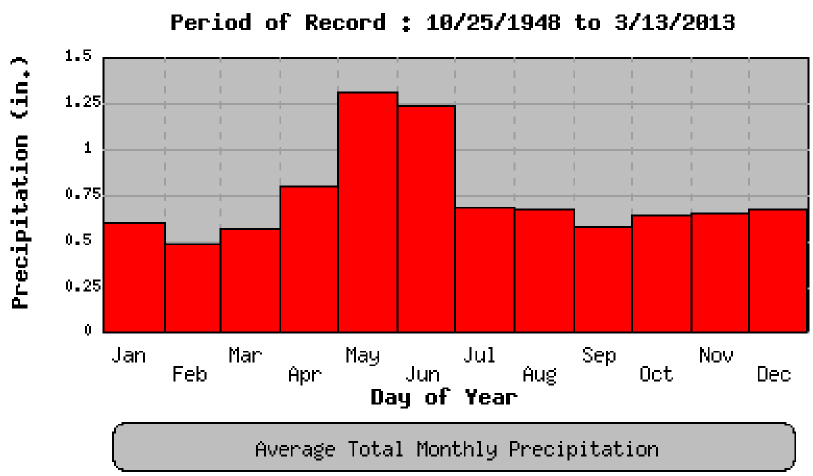

Figure 10. Average total monthly precipitation at Hamer, Idaho (station 103964) from 1948 to 2012. From Western Regional Climate Center (2013).

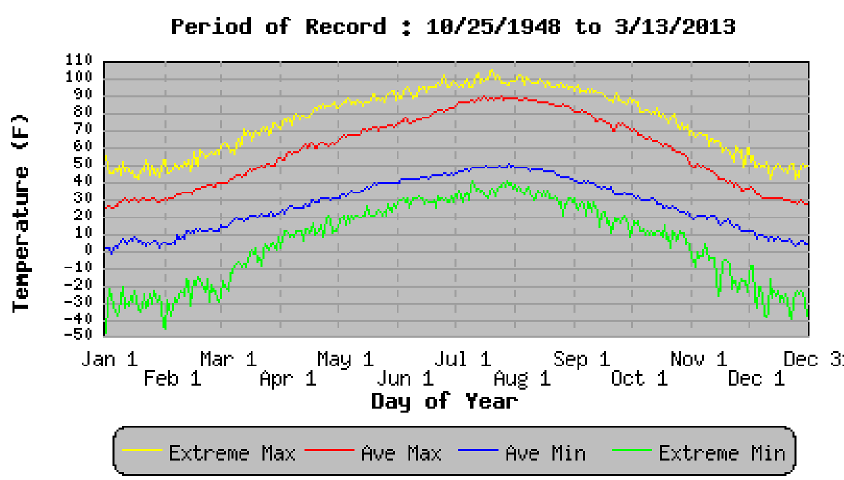

Figure 11. Average and extreme daily temperatures at Hamer, Idaho (station 103964) from 1948 to 2012. From Western Regional Climate Center (2013).

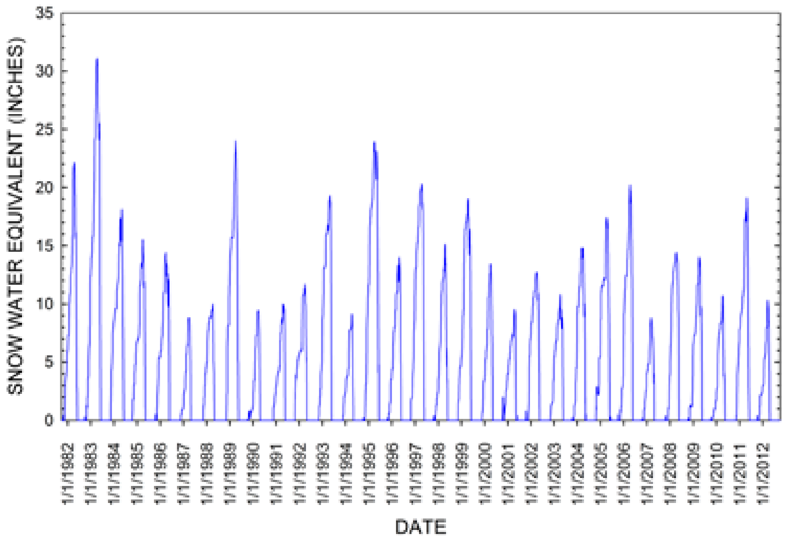

Figure 12. Snow water equivalent at Crab Creek SNOTEL station 424 in Idaho from October 1, 1981 through September 30, 2012. Data compiled from NRCS (2013b).

a decrease in the amount of precipitation falling as snow, which is reasonably well explained by summaries of seasonal climate at nearby stations (Hamlet et al. 2005, Mote et al. 2005, Knowles et al. 2006, Mote 2006). However, trends in 1 April SWE were better explained by changes in precipitation than temperature at higher elevations (Mote 2006, Hamlet et al. 2007). Earlier snowmelt also was related to increased evapotranspiration and earlier soil recharge indicated by increased soil moisture during spring (Hamlet et al. 2007).

Similar to regional trends in the western United States, average annual temperatures at Ashton, ID (60 miles east, northeast of CNWR) increased significantly (1.5 °F) from 1925 to 2010. This increase was likely driven by an increase in minimum temperatures because annual monthly minimum temperatures increased by 2.2 °F and annual monthly maximum temperatures showed no significant change (USFWS 2012). The downward trend in annual peak SWE at Crab Creek from 1982 to 2012 is not significant (Fig. 12). However, increases in air temperature at Ashton, ID were highest during the winter and spring (USFWS 2012).

Surface water

Precipitation in the ESRP, spring snowpack in the Centennial Mountains, timing of snowmelt, and river seepage historically influenced stream flow in the Beaver-Camas watershed. Important in the geologic history of the ESRP, alluvial sedimentation also is an important characteristic of current day streams. The waters of Camas Creek and other northern tributaries in the ESRP transport large quantities of alluvial material "held in suspension or rolled along their bottoms" forming alluvial fans at the mouths of tributary valleys and depositing finer sediments in depressions, sinks, or lake bottoms (Russell 1902:130).

Camas Creek is one of seven "lost rivers" of the ESRP, named so because after entering the plain they do not cross it. These northern tributary drainages do not have surface flow into the Snake River, but rather form "temporary lakes on the lava plains" (Russell 1902:26). Water in the Camas, Beaver, Medicine Lodge, Birch, Little Lost, and Big Lost drainages spreads out "on the marginal portion of the plain during the period of [the streams] greatest elongation and forms shallow lakes" (Russell 1902:130). During late September 1835, trapper

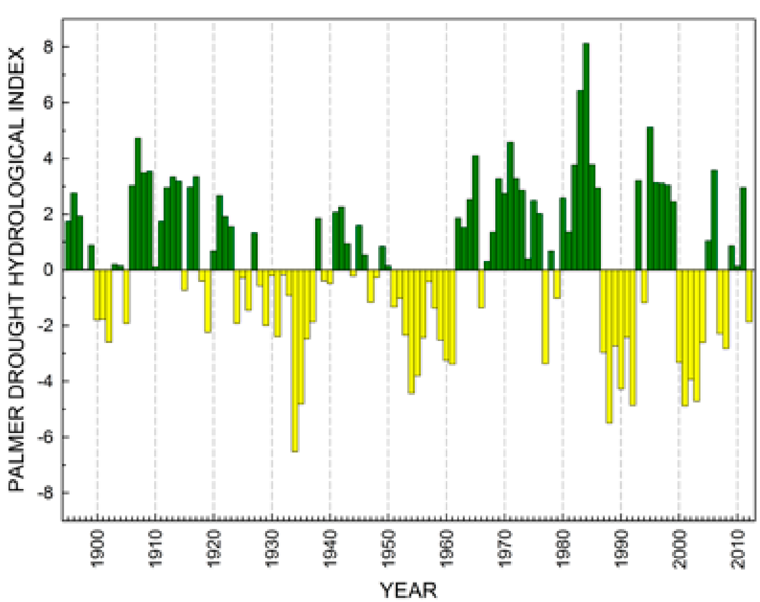

Figure 13. Palmer Drought Hydrological Index (PDHI) for Idaho Climate Division 9 (Upper Snake River Plains) from 1895 to 2012. Data compiled from NOAA (2013).

Russell Osborne traveled down Camas Creek to where it formed a lake and sank into the dry sandy plain (Haines 1965). Of the "lost river" tributaries, the Big Lost, Little Lost, Birch, and Camas drainages are major contributing drainages (USFWS 2012).

Not all of the stream flow leaving the Centennial Mountains reaches CNWR as surface water. Some of the stream flow in Camas and Beaver creeks seeps into the ground above CNWR, which recharges the aquifer under the ESRP. The average annual seepage during 1980-2008 from Camas Creek between Kilgore and Camas was almost 1.88 million cubic feet (ft^3) (43,145 acre-feet) (IDWR 2013), similar to measurement during 1921 when an estimated 51,190 acre-feet of stream flow seeped through the lava substrate (Stearns et al. 1939). The seepage from Beaver Creek increases downstream after it enters the ESRP. From Spencer to Dubois, the average annual seepage was 1.76 million ft^3 (4,045 acre-feet); from Dubois downstream, the average annual seepage was 7.09 million ft^3 (16,267 acre-feet; IDWR 2013). River seepage varies over time (Fig. 14) and appears to be independent of aquifer head so these estimates are likely representative of historical conditions.

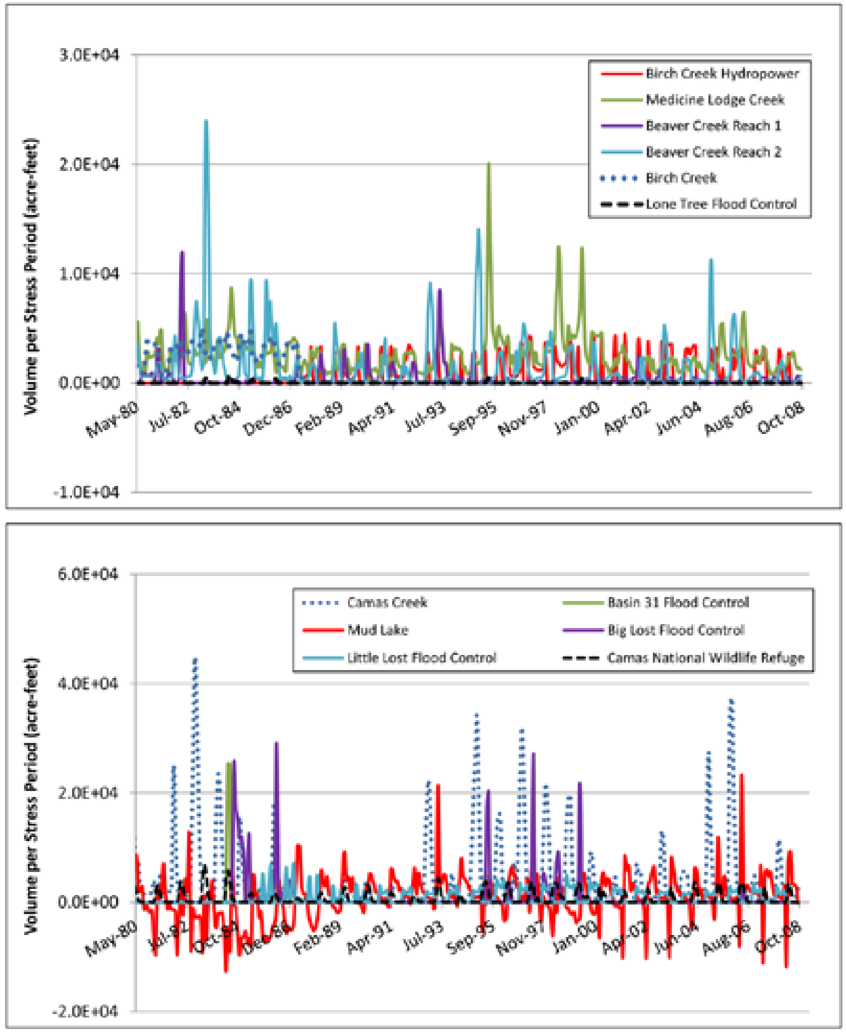

Figure 14. Non-Snake River seepage from Mud Lake, Camas National Wildlife Refuge, and northern tributary basins, including Beaver and Camas creeks. From IDWR (2013).

The Beaver-Camas subbasin is characterized by spring flooding from snowmelt and surface water runoff, followed by gradual drying with low or no water conditions during the summer and fall. Average monthly discharge for Camas Creek at Camas, ID (USGS station number 1311200),which is approximately 1 mile north of CNWR, peaks during May (193 cubic feet/second (ft^3/s)) and the majority of the flow occurs from April to June (Fig. 15) (USGS 2014). Annual peak flows for Camas Creek at Camas, Idaho range from 69 to 1,500 ft^3/s (Fig. 16); mean peak stream flow is 544 ft^3/s (USGS 2014). Nine of the ten peak discharges $\geq$ 1,000 ft^3/s have occurred since 1980. Portions of Camas Creek went dry during the fall or during drought periods. During September 1990, Camas Creek was dry for 20 or 30 miles upstream from Mud Lake, but contained underflow at a depth of 20 feet below the surface.

Stage-discharge measurements for Camas Creek at Camas from 2006-2012 are most available for stream flows < 400 ft^3/s (Fig. 17). The relationship between stream stage and discharge is highly variable at flows < 50 ft^3/s. Above that, estimates of stage-discharge suggest stream stage height increases approximately 0.5 feet per 70 ft^3/s increase. At higher discharges, the relationship likely flattens and becomes non-linear as flows into the floodplains increase. However, only six data points are available for discharge > 400 ft^3/s, so the exact relationship cannot be confidently estimated.

The dynamic nature of surface water on the ESRP (and its interaction with groundwater) prior to substantial anthropogenic modification is probably best portrayed by Merriam (1891:28-29) while describing the origin of the name Market Lake, which is southeast of CNWR. Prior to 1853, Market Lake was described by Governor Stevens as an "immense prairie bottom or basin, and a favorite resort for game of all kinds," that was visited by trappers and mountain men who referred to it as the "market." At some unspecified date, the basin was "converted into an immense sheet of water" attributed to the rising of subterranean flow that originated from mountain streams before sinking in the sand or sage desert. By 1890, Merriam (1891) noted that Market Lake was dry and occupied by ranches, likely as a result of drought (Cook et al. 2007) and irrigation ditches and railroad embankments, which had already altered its hydrology (Russell 1902).

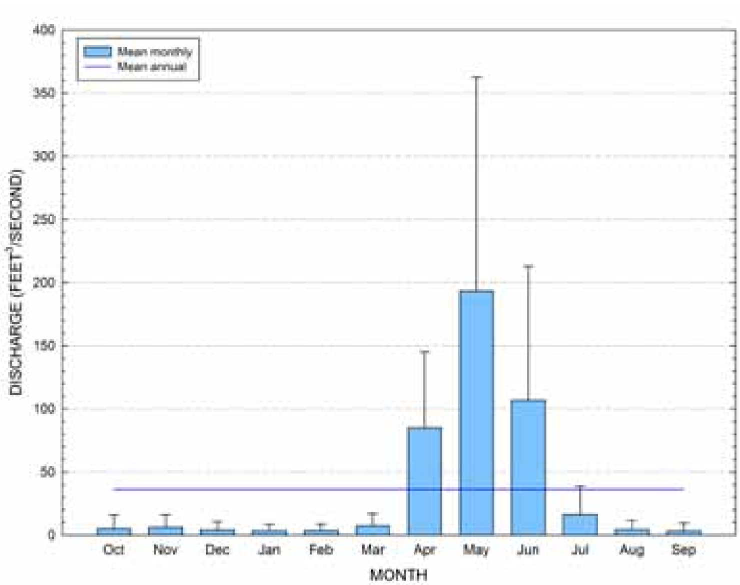

Figure 15. Mean monthly and mean annual discharge at Camas Creek, Camas, Idaho (USGS station 13112000) during 1925-2013. Data compiled from USGS (2014).

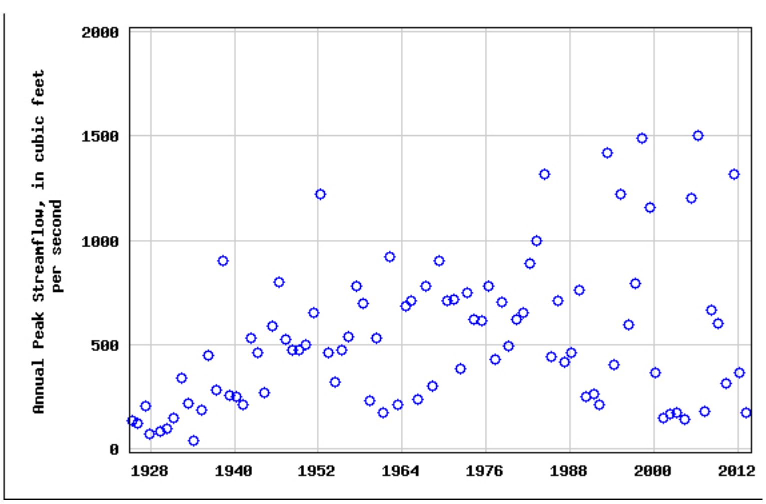

Figure 16. Water year (October 1 – September 30) peak stream flow at Camas Creek (Camas, Idaho) from 1925 to 2013. From USGS (2014).

Water level fluctuations described for Mud Lake also indicate a very dynamic water regime and are likely representative of the temporal changes in surface water at CNWR. The surface area of Mud Lake fluctuated monthly and yearly from a dry lakebed (as observed during 1891) to an area of 40 to 50 square miles (25,600 to 32,000 acres) at its maximum extent (Russell 1902). No dates are given for when the maximum extent of the lake occurred so no comparison can be made to historical climatic conditions. However, extreme or very wet conditions occurred throughout a large portion of the western United States during 1867-1869 and 1876-1878 (Cooke et al. 2007). It is possible that these conditions resulted in a large increase in the surface area of Mud Lake, as well as the increased flooding at Market Lake. Even if the maximum extent of Mud Lake was exaggerated, fluctuating between a dry lakebed to an area of 13,000 to 16,000 acres (50% of Russell's estimate) is a significant hydrological change.

Mud Lake was noted as the only lake on the ESRP that did not go dry every summer. The 1899 meander line of Mud Lake indicated a surface area of 2,460 acres with dry lakebeds to the south and west totaling 3,000 acres (Stearns et al. 1939). Mud Lake was lower during summer 1900 than at any time during the preceding nine years and was described as a mud flat from a few to several miles wide (Russell 1902:130).

Groundwater

The groundwater aquifer underlying the ESRP is a vast and important water resource with spatially and temporally variable water movement and water storage capacity due to the heterogeneity of numerous basalt flows and interbedded sedimentary deposits. Quaternary and some late Tertiary basalts, with higher hydraulic conductivity than the underlying Tertiary basalt, form the primary unit of the ESRP. Due to complex geologic stratigraphy, the ESRP aquifer has variable interconnections with surface water. Little is known about the condition of the aquifer prior to the late-1800s when surface and groundwater developments were initiated in the ESRP. Only five wells have data from prior to 1901 (Garabedian 1992). Because those wells are located in the western region of the ESRP, they are not likely indicative of groundwater conditions at CNWR. However, several studies model and examine changes in aquifer characteristics during the 20th century as a result of surface and groundwater developments (e.g., Spinazola 1994a, Lindholm 1996, Ackerman et al. 2006). These studies provide insights into the hydrogeology that historically supported diverse habitat types at CNWR.

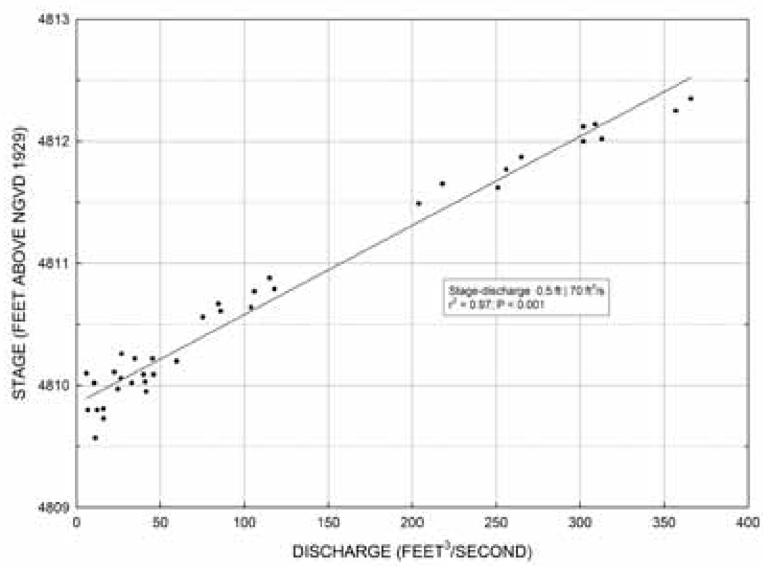

Figure 17. Stage-discharge relationship for Camas Creek at Camas, Idaho (USGS station number 13112000). Data compiled from annual USGS water data reports for 2006-2012. Available on-line at http://waterdata.usgs.gov/nwis.

Estimated total annual recharge to the aquifer ranges from 6.2 to 8 million acre-feet (Mundorff et al. 1964, Garabedian 1992, IDWR 2013). The aquifer is recharged by: 1) underflow from tributary basins; 2) losses (or seepage) from tributary streams entering or crossing the plain; 3) losses from the Snake River, 4) downward percolation/infiltration of precipitation and snowmelt; 5) infiltration of applied irrigation water. Discharge from the aquifer (including natural and human-influenced) is through: 1) gains to the Snake River; 2) gains to tributary streams; 3) springs; 4) groundwater pumping for irrigation (Graham and Campbell 1981, Garabedian 1992, IDWR 2013).

Underflow from tributary basins is a significant component of water yield from the watershed that recharges the ESRP aquifer. Estimated mean total annual water yield (underflow and streamflow) for the northern tributary drainages was over 1 million acre-feet, but only 280,000 acre-feet was measured as streamflow (Kjelstrom 1995). Estimated underflow from the Camas Creek drainage basin ranged from 129,540 to 155,000 acre-feet/year. Estimated underflow from the Beaver Creek drainage basin ranged from 55,517 to 62,000 acre-feet/year (Garabedian 1992, IDWR 2013).

Based on groundwater levels measured during spring 1980, the water table gradient is as low as 3 feet/mile between the 4,700-foot water table contour north of Mud Lake and the 4,900 foot water table contour north of Dubois (Fig. 18). The water table gradient steepens to 30 feet/mile south of Mud Lake (Spinazola 1994a). The estimated hydraulic conductivity for the aquifer ranged from 0.0004 to 0.4 feet/second (Garabedian 1992, Whitehead 1992). Hydraulic conductivity generally decreases with depth in the aquifer due to the filling of porous basalt with calcite, silica, and clay minerals (Wood and Low 1988). Horizontal movement of water is highest in the porous and highly permeable interflow zones, areas of "highly fractured vesicular basalt and cinders that compose the top of one flow zone and the base of the overlying flow" (Whitehead 1992:B26). Hydraulic conductivity may be low in the central part of a flow that has high permeability on the top and bottom. In addition, differential cooling and overlapping of flows from adjacent sources can create areas where water ponds, evaporates or percolates to the regional water table (Whitehead 1992).

The basalt aquifer is generally an unconfined system, but dense, unfractured basalt and layers of fine-grained sediment with low hydraulic conductivity act as locally confining beds in some areas of the ESRP. The fine-grained sediments from pluvial Lake Terreton confine water in underlying sand, gravel and basalt aquifers in the Mud Lake area holding it under pressure and likely reduce overall aquifer transmissivity (Garabedian 1992). Head differences between the water under the confining beds

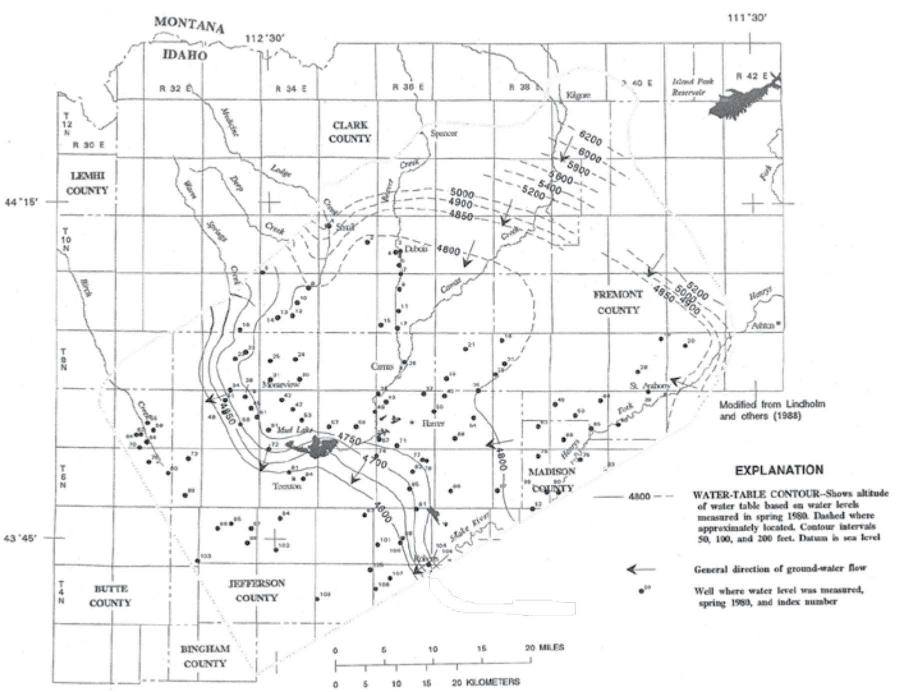

Figure 18. Altitude of water table and direction of groundwater flow based on water levels measured during spring 1980 in the Mud Lake area. From Spinazola (1994a).

averaged 46,100 acre-feet and decreased to 31,000 acre-feet by 1929. Springs northwest of Mud Lake that discharged 25,000 acre-feet during 1922 and 1923 also appeared to decline by 1929 (Stearns et al. 1939). Two distinct springs at Sandhole Lake were observed during 1922, but were not found during 1928 (Stearns et al. 1939). Spring discharge is affected by variations in weather and irrigation recharge (IDWR 2013), but it is unclear how much of the discharge reported by Stearns et al. (1939) is attributable to increased irrigation recharge and how much was due to above average wet conditions. The fact that some springs present in the early- to mid-1920s during a wet period had disappeared by the late-1920s when drought conditions occurred suggests that variations in weather patterns have contributed to groundwater discharge at Mud Lake and CNWR.

and water in unconfined setting in the Mud Lake area are not reported, but water levels in wells completed below fine-grained lakebeds at the northeast end of American Falls Reservoir are approximately 20 feet higher than water levels in wells drilled in the shallow alluvium (Garabedian 1992).

Groundwater levels northeast of Mud Lake at CNWR indicate vertical water movement (Spinazola 1994a). Stream and lake gains to Rays Lake and to Camas Creek downstream of Rays Lake also indicate discharge of water to these areas from the water table. This pattern of groundwater flow was also recognized in the early-1900s when the water table was 25 feet below the surface at the Camas gauging station and came closer to the surface downstream until it formed sloughs in the vicinity of Hamer (Stearns et al. 1939). Fluctuation of water in wells also varied across short distances with wells at Hamer having less fluctuations in water levels compared to wells near Mud Lake.

Except for areas of large historical discharges, the Presettlement distribution of smaller springs and seeps is not known. Stearns et al. (1939) states that there were thousands of seeps and springs in the marshy area tributary to Mud Lake that averaged 75 second-feet during 1923. Annual discharge from these springs during 1922-1927

Spring discharge in the ESRP is much higher in the regions of Blackfoot to Neeley and Milner to King Hill where most springs discharge from the basalt of the Snake River Group north of the Snake River. The altitude of these springs is controlled by 1) altitude of the contact between relatively impermeable Banbury basalt and basalt of the Snake River group 2) location of clay lakes, and 3) location of relatively impermeable Idaho Group sedimentary rocks (Garabedian 1992:F17). Springs also discharge from talus aprons. Vertical movement is dependent on the degree of fracturing and the presence or absence of fine-grained intercalated sedimentary rocks that may impede movement.

Fine-grained sedimentary deposits above the regional water table also form perched aquifers in the Mud Lake area and Big Lost River valley that result in significant head changes with depth (Garabedian 1992, Lindholm 1996). Stearns et al. (1939) recognized both the confining characteristics and perched water abilities of the tight beds of clay in the Mud Lake region, stating that these clay beds had "greater practical value in preventing water from sinking than in creating artesian conditions" (Stearns et al 1939:43). Mud Lake and the water found in shallow wells in the vicinity of the lake formed a perched body of water that was a few hundred feet above the water table to a deeper body of groundwater (Stearns et al. 1939).

HISTORICAL FLORA AND FAUNA

Overview

Natural climatic variability and multidecadal changes in precipitation and temperatures were primary drivers of ecosystem process and species distributions in the Rocky Mountains and Upper Columbia Basin (see summary in McWethy et al. 2010). Beginning with its dynamic geologic formation and continuing through climatic variations during the Holocene, the ESRP ecosystem was a dynamic and heterogeneous landscape with gently rolling topography, diverse forms of volcanic rock outcrops, water-transported alluvium and lacustrine sediments, and active stream drainages with sinks and subterranean flows that crossed and sometimes surfaced on its otherwise arid, broad, and gently rolling landscape.

Surface and groundwater inputs across heterogeneous soil surfaces created a diverse mosaic of sagebrush steppe, riparian, and wetland habitats at CNWR. Highly variable seasonal, annual, and interdecadal precipitation within the watershed resulted in variable extents of surface water flooding across CNWR. Groundwater discharge and stream flow during wet years, likely contributed perennial water sources to some areas. Observations during the 1940s (USFWS refuge annual narratives) and during the high spring 2011 snowmelt period suggest that the heterogeneous spatial distribution and vertical profiles of soils create a complex interaction between ground and surface water movements. Although not quantified prior to substantial surface water developments, this interaction maintained the productive and diverse wetland habitats at CNWR.

Prior to the first biological reconnaissance of south central and southeast Idaho during 1890, the natural history of Idaho was not well known compared to other states or territories (Merriam 1891). Narratives of early explorers or trappers included notes on animals observed. General vegetation communities were recorded on maps and survey notes from the General Land Office (GLO) surveys from 1881 to 1899. Because most of these written descriptions of vegetation communities for the ESRP occurred during a period of drought in the western United States (Cook et al. 2004, Cook et al. 2007), and subsequent accounts occurred after substantial anthropogenic changes had altered the natural hydrology, limited information is available to document the natural range of variability in historical upland and wetland habitat types at CNWR.

Historical Vegetation Communities

Vegetation communities at CNWR historically ranged from high desert sagebrush steppe habitats on the well-drained sandy uplands to riparian meadows along Camas Creek and nearly permanently-flooded wetlands at Sandhole Lake. Temporally variable disturbance regimes (e.g., flooding, drought, wildfires) resulted in a highly dynamic ecosystem where different vegetation communities may have naturally occurred at a single location over time. Therefore, the precise distribution of historical vegetation communities at CNWR likely varied depending on climatic conditions (e.g., van der Valk and Davis 1978, Connelly et al. 2004). The distribution of native plant species reflected their adaptations to variable timing, depth, duration, and extent of annual flooding (hydroperiod), underlying soil characteristics including salinity and pH, wildfire, and herbivory by wild game. Plant species expected to occur at CNWR are listed in Appendix A.

Recognizing the annual variation in precipitation and flooding regimes, we developed an HGM matrix of potential historical vegetation communities related to geomorphic landform, soil, and hydrologic condition (Table 2). These vegetation communities were then mapped based on characteristics and distribution of soil types (Soil Conservation Service 1979, NRCS 2008, 2012), vegetation communities recorded in GLO survey notes and maps from the late-1800s (Figs. 19,20; David 1881a,b; McCoy 1884a,b; Alley 1899; Alley and Turley 1899) and other historical accounts, and ecological characterizations of habitats in the Intermountain West (e.g., Youngblood et al. 1985, Connelly et al. 2004). The earliest habitat maps and aerial photos available for CNWR from the 1930s and 1940s (Figs. 21, 22) reflect conditions following substantial anthropogenic alterations on the ESRP. Elevation data, while useful for understanding general surface water flow patterns, was not used to delineate historical vegetation communities due to extensive anthropogenic modifications (e.g., ditches, berms, borrows, field leveling, dynamiting, etc.). The distribution of HGM-predicted vegetation communities (Figs. 23, 24) assumes:

1. Vegetation conditions reported during the late-1880s and 1890s are representative of a dry period (Cook et al. 2004, Cook et al. 2007).

2. The vegetation community listed as "bunchgrasses" on GLO survey notes by McCoy (1884a,b) was used to describe areas of herbaceous upland or wetland vegetation because in some areas sagebrush was listed as the dominant vegetation community and in other areas it was both sagebrush and bunchgrasses. We believe this assumption is accurate because

Table 2. Hydrogeomorphic (HGM) matrix of the historical distribution of major vegetation communities at Camas National Wildlife Refuge in relationship to surficial geology, landform, parent material, soils, and hydrological regime. Relationships were determined based on the Jefferson County soil survey (Soil Conservation Service 1979), soil descriptions (NRCS 2008, 2012), and historical maps and aerial photographs. Descriptions of vegetation communities are based on life-history characteristics of native plants and ecological characterizations of community types (e.g., Cronquist et al. 1972, Youngblood et al. 1985, Windell et al. 1986, Connelley et al. 2004) and are described in the text.

Habitat Type	Geologic surface	Landform	Parent Material	Soil Type(s)	Hydrologic regime
Sagebrush steppe	Tholeiite lava flow Loess	Lava plains	Eolian Mixed alluvium Bedrock	Diston loamy sand Grassy Butte sand Grassy Butte loamy sand Grassy Butte-Medano complex Grassy Butte-Rock outcrop complex Matheson loamy sand Matheson sandy loam Rock outcrop-Bondfarm complex	Dry
Salt desert shrub/ grassland	Loess	Relict lakebed	Lacustrine	Terreton loamy sand Terreton sandy loam Terreton sandy clay loam Zwiefel fine sand Zwiefel loamy sand	Ephemeral and/or saturated subsurface soil
Alkali/saline wet meadow	Loess	Relict lakebed	Lacustrine	Levelton loam, moderately saline-alkaline Montlid-Heiseton complex	Temporary
Wet meadow	Loess	Depressions on lakebeds	Lacustrine	Levelton loamy sand	Temporary
Short emergent marsh	Loess	Relict lakebed	Lacustrine Mixed alluvium	Levelton-Medano complex Medano complex	Seasonal
Robust emergent/ submerged aquatic vegetation	Loess	Relict lakebed	Lacustrine	Fluvaquents Water (except Sandhole L)	Semi-permanent
Open water/ submerged aquatic vegetation	Loess	Relict lakebed	Lacutrine	Water (Sandhole L only)	Permanent
Riverine	Loess	Creek channel through relict lakebed	Mixed alluvium	Varies	Semi-pemanent
Riparian herbaceous marsh	Loess	Relict lakebed adjacent to creek channel	Primarily mixed alluvium	Poorly drained soils adjacent to creek channel: Medano-Psammaquents complex Medano complex Levelton-Medano complex	Seasonal

sagebrush and bunchgrasses occurred on more poorly drained lacustrine deposits and sagebrush generally occurred on soils over lava plains (Soil Conservation Service 1979, NRCS 2008, 2012).

3. Average long-term wet and dry periods occurred for 15 to 20 years each (NOAA 2013) that contributed to a relatively long wet-dry cycle of 30 to 40 years.

4. The increase in groundwater levels and groundwater discharge observed during the early-1900s were a result of increased irrigation with surface water (Stearns et al. 1939) and above average wet conditions (Cook et al. 2004, NOAA 2013). It is unknown how much each of these factors individually contributed to observed changes in groundwater of the regional ESRP and the shallow Mud Lake alluvial aquifers compared to the late-1800s.

5. The natural drainage classes of soils have not been affected by anthropogenic actions because alterations (e.g., ditches, berms) have not significantly changed the morphology of the soil (Soil Survey Division Staff 1993).

6. Areas mapped as low value grazing characterized by sagebrush (Fig. 21) that overlie soils currently mapped as poorly and very poorly drained lacustrine deposits (Fig. 6) represent soil inclusions at a finer scale than currently mapped by NRCS.

During the 1884 GLO subdivision surveys, bunchgrasses and sagebrush were more frequently listed as vegetation communities within the present-day boundary of CNWR compared to areas to the north and west where vegetation was predominantly described as sagebrush (McCoy 1884a,b). The northern and western boundaries of T7N R35E (outside of CNWR) were described as "high rolling plains destitute of water," but no details on vegetation were provided (David 1881b:364). During the late-1890s, the western portion of CNWR was described as "level and rolling prairie lands" with areas of dense or scattered understory (Alley 1899:641). The soils were classified as 1st or 2nd rate, capable of producing good crops when irrigated. Spatial variation in bunchgrass dominated meadows and sagebrush/bunchgrass dominated meadows may have resulted from differences in past disturbance history and/or soil characteristics. An area to the west of East and Middle Buttes, about 200 square miles, was "clothed with luxuriant bunch grasses, and furnishes as typical as example of a rolling prairie as one can find in the far West," without trees, shrubs, or even sagebrush (Russell 1902:23). This was in the vicinity of the Big Lost River and may have been similar to the areas of bunchgrasses mentioned in the GLO surveys for CNWR; therefore, "bunchgrasses" may have referred to alkali/saline, wet, or dry meadows, or even possibly emergent marsh habitats during a dry period.

Sagebrush steppe — This vegetation occurred on sandy soils, predominantly overlying lava plains. High variation in total annual precipitation characteristic of the semi-arid climate at CNWR (and throughout the range of sagebrush steppe), created conditions favorable for deeply rooted shrubs during drought years and promoted more shallowly-rooted herbaceous plants during wet years (West 1999b). This dynamic was evident in sagebrush steppe habitats at the Idaho National Laboratory (INL), southeast of CNWR when perennial grass cover was only 0.5% during 1950 and increased 13-fold by 1975 following a 15-year period of wet conditions (Anderson and Inouye 2001). Sagebrush steppe at CNWR was also mapped on areas of low grazing value (Fig. 21) within poorly and very poorly drained soils.

Although the amount of sagebrush versus herbaceous cover during historical pre-settlement conditions is often debated, the herbaceous component of sagebrush communities in the Intermountain sagebrush steppe is more prominent than in the Great Basin sagebrush communities (West 1983, Connelly et al. 2004). State and transition models of dynamics of sagebrush habitats identify shifts between bunchgrass dominated and sagebrush/bunchgrass dominated habitats resulting from fire return intervals as the main succession pathways for these habitats during the pre-settlement period (Connelly et al. 2004). In addition to wildfire and variation in precipitation, shrub die-off may also occur as a result of increased soil salinity, parasites, disease, and insects (McArthur et al. 1990).

The dominant shrub component of sagebrush steppe at CNWR was basin big sagebrush (*Artemisia tridentata tridentata*) and Wyoming big sagebrush (*A. t. wyomingensis*). Historically, big sagebrush was abundant in areas of dry soil except where fires had recently occurred or in cultivated areas (Russell 1902). Sagebrush plants were found as large as 10

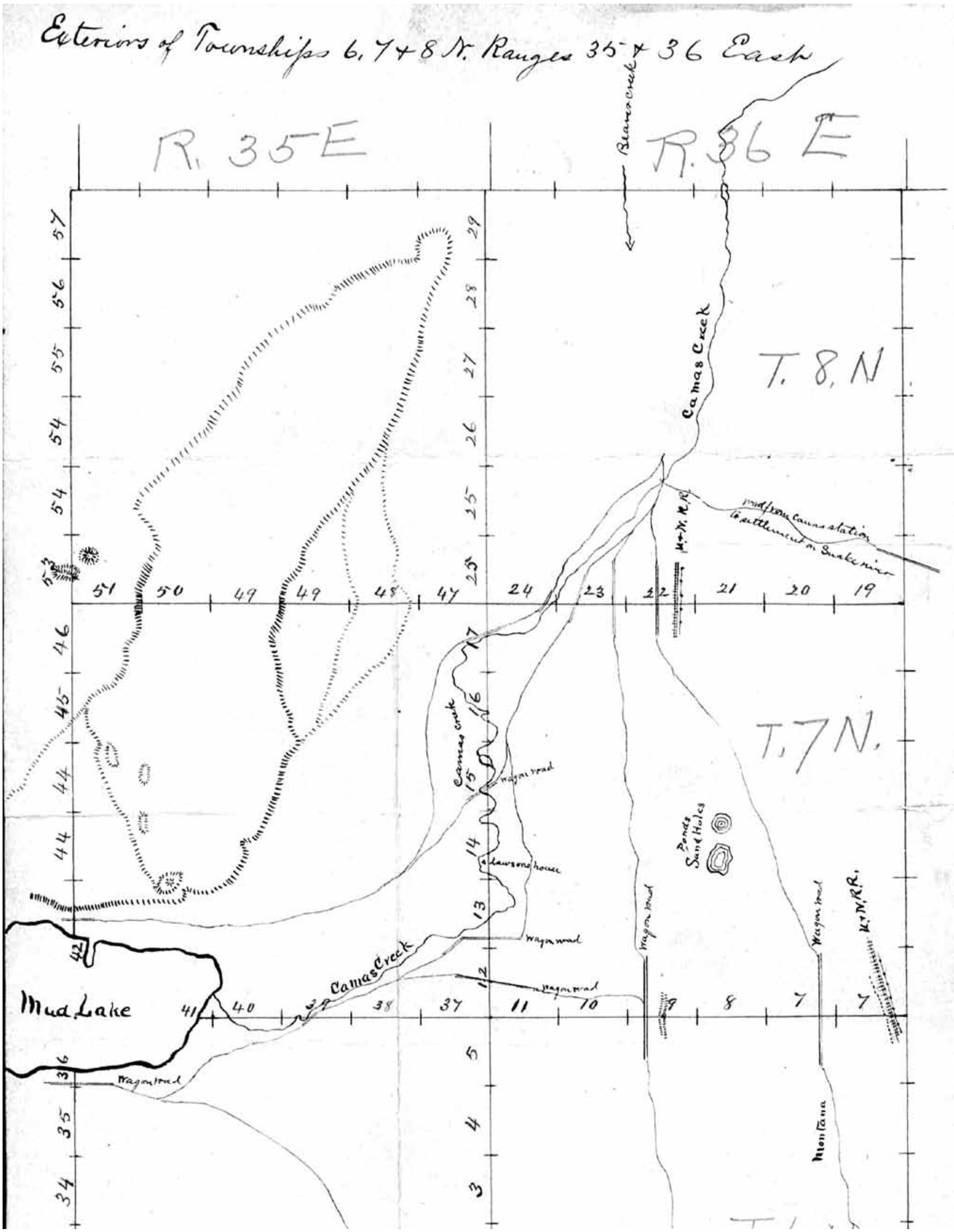

Figure 19. General Land Office survey map of the exterior boundary of townships 6, 7, and 8 north and ranges 35 and 36 east (David 1881b). Map from Bureau of Land Management General Land Office Records available on-line at http://www.glorecords.blm.gov/search/default.aspx.

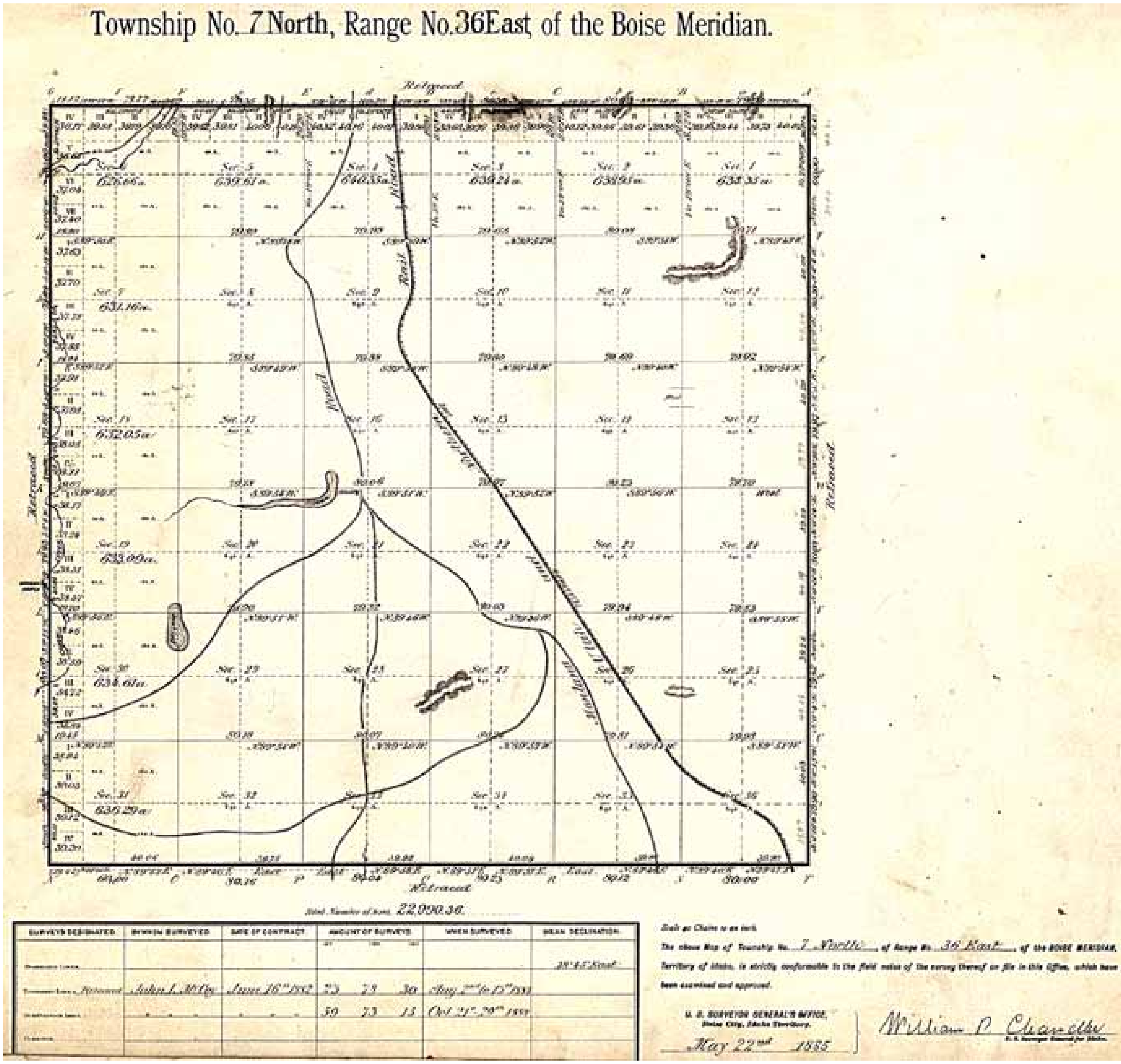

Figure 20. General Land Office survey map of Township 7 North, Range 36 East, surveyed during October 1884 (McCoy 1884a). Map from Bureau of Land Management General Land Office Records available on-line at http://www.glorecords.blm.gov/search/default.aspx.

feet tall, but more commonly were less than three feet tall and spaced six to eight feet apart. Several species of rabbitbrush (*Chrysothamnus* sp.) were also plentiful and noted for its brilliant yellow color during the fall.

Although not identified to species, many herbaceous species were noted blooming during early spring and yellow sunflowers provided dashes of color during the summer and fall (Russell 1902). Bunchgrasses were described as abundant and nutritious "and still furnished pasturage where sheep have not ravished the land" (Russell 1902:22); dense undergrowth was commonly noted during the 1899 subdivision survey of T7N R35E (Alley and Turley 1899). Indian ricegrass (*Achnatherum hymenoides*) was noted as common during 1890, but comprehensive identification of other herbaceous species is lacking, in part due to the timing of field work during late August when most of the herbaceous plants had stopped flowering or had disappeared altogether (Merriam

1891). False mallow (*Malvastrum* sp.) and two or three cactus species were also identified (Merriam 1891). Native herbaceous vegetation reported from recent surveys that were likely present during the pre-settlement period include needle and thread (*Hesperostipa comata*), western wheatgrass (*Pascopyrum smithii*), and threadleaf sedge (*Carex filifolia*).

Threetip sagebrush (*Artemisia tripartita tripartita*), and antelope bitterbrush (*Purshia tridentata*) were common at the higher elevations (Merriam 1891) outside of the present-day CNWR. Average elevation of threetip sagebrush for the entire Snake River Plain is 5,614 feet compared to 4,816 feet for basin big sagebrush (Connelly et al. 2004). Threetip sagebrush is also characterized by slightly higher precipitation, deeper soils, lower soil salinity, and higher available water capacity (Connelly et al. 2004). The dominant sagebrush species in valleys extending north from the ESRP varied with big sagebrush prevalent in Birch Creek Valley and threetip sagebrush prevailing in the Little Lost River Valley (Merriam 1891). No reconnaissance of the Camas or Beaver creek drainages was made, but species were likely similar to those reported from other valleys with elevation, slope, precipitation and soil salinity determining the distribution of sagebrush species (Connelly et al. 2004).

Presettlement fire regimes varied spatially and temporally throughout sagebrush communities in the western United States depending on climate conditions, soil-driven variation in fuel loads, species composition, and succession stage of the sagebrush community (Miller and Tausch 2001, Connelley et al. 2004, Miller and Heyerdahl 2008). Although fire return intervals are debated, variable fire intensity and return intervals created a spatially and temporally dynamic mosaic of sagebrush types or successional stages across the landscape (Miller and Eddleman 2001, Connelley et al. 2004).

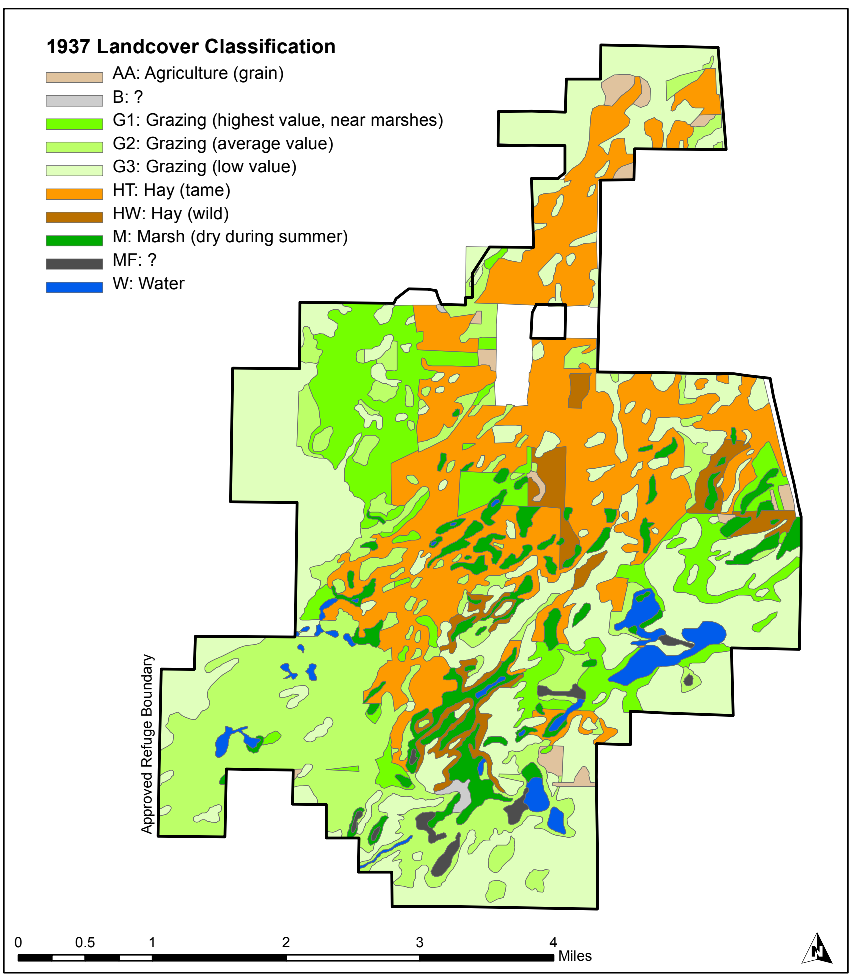

Figure 21. Landcover map of Camas National Wildlife Refuge from 1937 (digitized by U.S. Fish and Wildlife Service).

The Presettlement recurrence interval of fire in sagebrush steppe communities at CNWR is not known, but can be inferred from fire intervals in other western sagebrush areas. Presettlement mean fire return intervals (MFRI) for Wyoming big sagebrush communities ranged from 50 to 100 years, but information on the range of variability in fire return intervals is limited (Miller and Tausch 2001). However, considering recovery rates of Wyoming big sagebrush and correcting MFRI for unburned areas and adjacency, fire intervals may have been 100 to more than 240 years in Wyoming big sagebrush communities (Baker 2006). Sagebrush species are long-lived after the seedling stage, and these species appear to thrive best under longer fire recurrence intervals in these arid settings.

Salt Desert Shrub/Grassland — Areas of Terreton and Zwiefel soils were mapped as salt desert shrub/grassland. These areas differ from soils mapped as sagebrush because they occur on

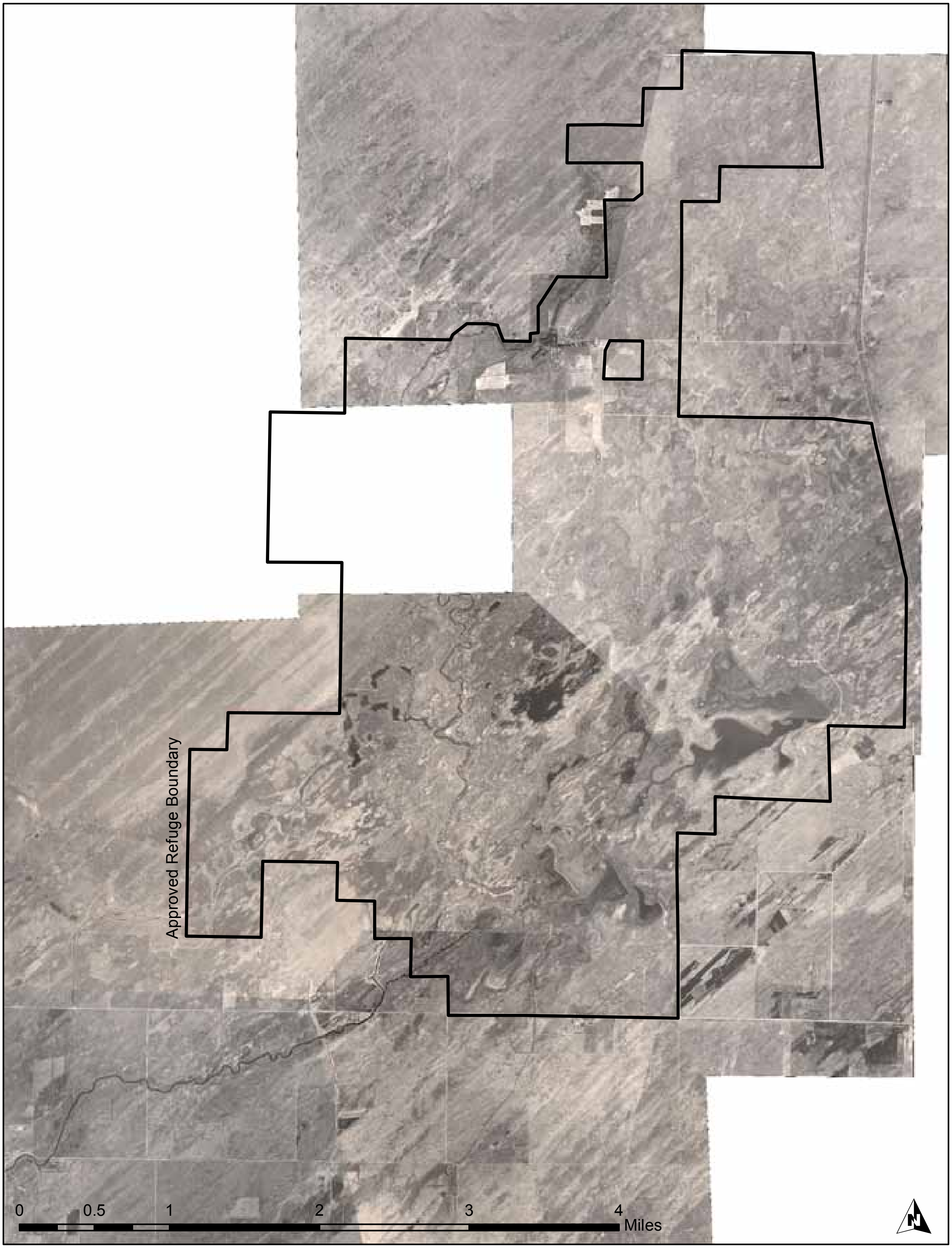

Figure 22. 1941 Aerial photo mosaic of Camas National Wildlife Refuge.

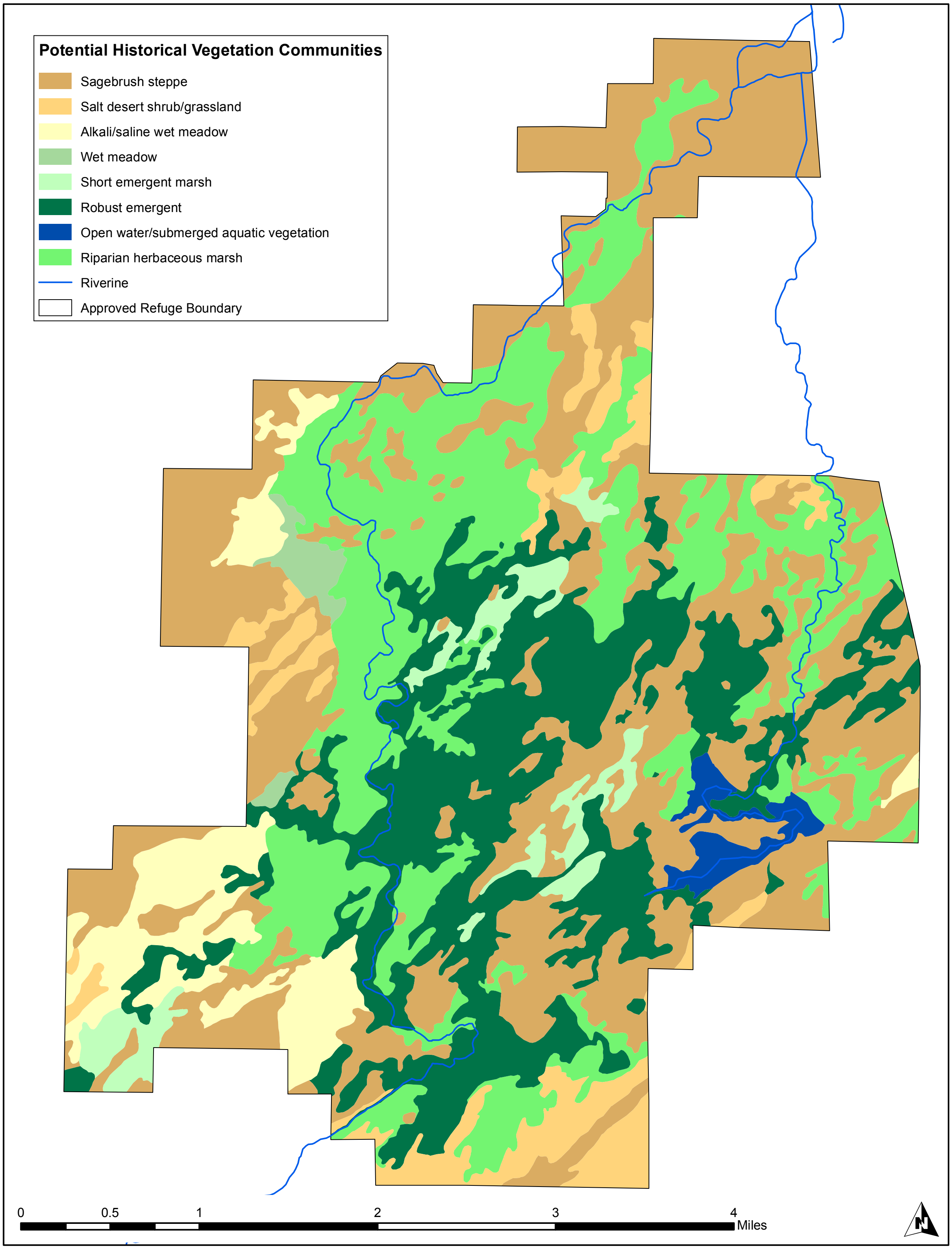

Figure 23. Extent and distribution of potential historical vegetation communities at Camas National Wildlife Refuge modeled from soil type descriptions and maps (Soil Conservation Service 1979, NRCS 2008, 2012), historical GLO maps and survey notes (David 1881a,b, McCoy 1884a,b, Alley 1899, Alley and Turley 1899), and characteristics of native plants.

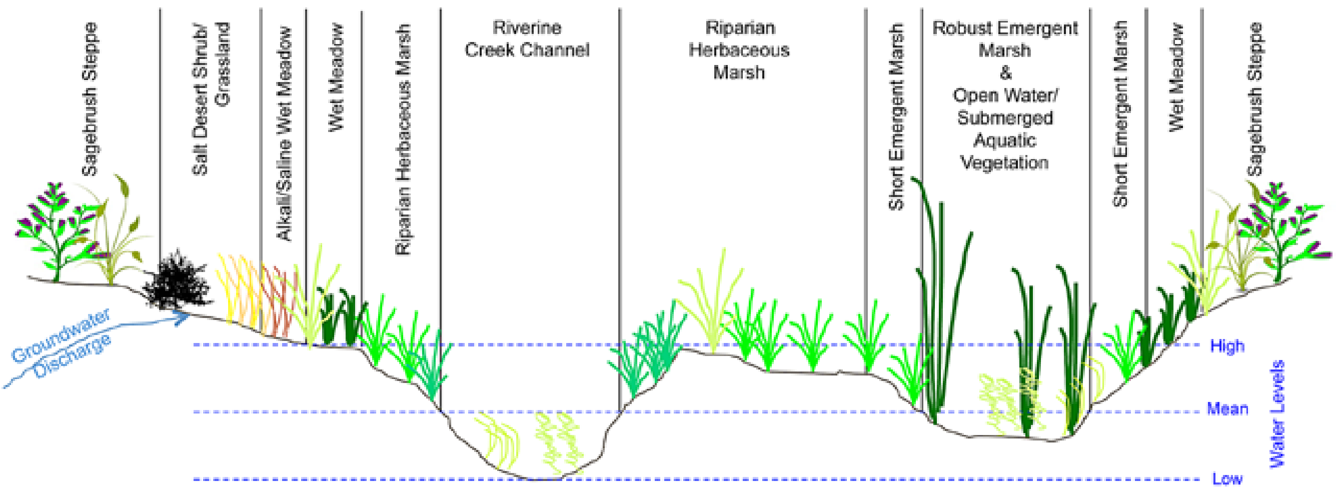

Figure 24. Generalized cross-section of historical vegetation communities at Camas National Wildlife Refuge based on elevation, groundwater, and surface water inputs.

relict lakebeds and have at least one subsurface soil layer with clay content ranging from 35 to 60% clay (NRCS 2012). Due to the dominant influence of clay particles on overall soil properties, soils with 40% clay or more are considered within the "clayey" USDA soil texture group (Sprecher 2001). Sagebrush grows best in deep, fertile soils, and cannot survive flooding or saturated soil conditions, and is therefore not likely to occur on these sandy and sandy loam soils on the relict lakebed where saturated subsurface soils may occur. Black greasewood (*Sarcobatus vermiculatus*), tolerant of ephemeral flooding and alkaline conditions, was noted south of Rays Lake on Zwiefel sand during 1884 (McCoy 1884a). Vegetation species of salt desert shrub communities described as characteristic on the ESRP during 1890 included spiny saltbush (*Atriplex confertifolia*), fourwing saltbush (*Atriplex canescens*), birdfoot sagebrush (*Artemisia pedatifida*), spineless horsebrush (*Tetradymia canescens*), winterfat (*Krascheninnikovia lanata*), and nodding buckwheat (*Eriogonum cernuum*) (Merriam 1891). Other species that likely occurred in this habitat included alkali sacaton (*Sporobolus airoides*), poverty weed (*Iva axillaris*), water groundsel (*Senecio hydrophilus*), and salt grass (*Distichlis spicata*) (Cronquist et al. 1972). Depressions within the salt desert shrub/grassland may have support alkaline/saline wet meadows at a finer scale than can be mapped with the current data.

Wetlands and Riparian Habitats — Lacustrine and alluvial deposits at Mud Lake and CNWR from fine suspended sediments transported by the lost rivers to pluvial Lake Terreton formed a perched water table that supported various wetland vegetation communities. These wetland habitats were hydrated by annual, seasonal, and long-term variable overbank flooding from Camas, Beaver, and Warm creeks. Local precipitation, areas of shallow groundwater, and the interaction of surface flows with groundwater also contributed to hydrologic characteristics of wetland habitats at CNWR. Snowmelt filled small depressions and formed water pockets (Russell 1902) that likely supported temporarily flooded wetland habitats. Areas of permanently flooded wetlands were limited.

Although generally restricted in the arid Intermountain West, riparian habitats were diverse during Presettlement times, occurring across large environmental gradients and at irregular intervals along stream corridors (Patten 1998). Riverine and riparian habitats occurred along Camas, Beaver, and Warm creeks within CNWR. Camas Creek meandered across the eastern and southern boundaries of T7N R35E 15 times during 1899. The creek width and direction of flow was measured at each section line. The measured widths of Camas Creek ranged from 50 to 260 links (33 to 172 feet) on 20-23 May 1899 (Alley 1899); creek depth was not recorded.

Elevation and its effect on frequency of inundation are the most important factors related to the distribution of riparian plant communities (see Fig. 24). Fluvial geomorphic processes, soil characteristics, stream gradient, flow regime, and geology also affect characteristics of riparian habitats (see summary in Briggs 1996). Flood pulsing and floodplain connectivity are essential aspects of primary and secondary succession in riparian zones that drive multiple ecological processes (Briggs 1996, Middleton 2002). The relatively low gradient and wide floodplain of Camas Creek at CNWR where water historically spread out across the alluvial aquifer likely created flooded conditions that restricted areas suitable for germination of woody species and/or created saturated soil conditions that reduced growth of woody species. Instead these areas supported herbaceous riparian communities that were documented in historical accounts.

During the 1881 township boundary surveys, the eastern boundary of T7N R35E, within the present-day CNWR, contained "considerable good land along Camas Creek" (David 1881b:364). Meadows were described adjacent to some areas of Camas Creek during the late-1890s. North of the present day CNWR Camas Creek was also characterized by good hay lands (David 1881a). Beaver Creek was described as a dry creek bed during early September 1881 (David 1881a).

Although the herbaceous community composition was not documented in historical accounts, it likely included graminoid-dominated community types currently present in southeastern Idaho described by Youngblood et al. (1985). Riparian herbaceous communities were likely dominated by sedges (water sedge [*Carex aquatilis*], slough sedge [*C. atheroides*], beaked sedge [*C. rostrata*], smallwing sedge [*C. microptera*], and Nebraska sedge [*C. nebrascensis*]). Forbs, Baltic rush (*Juncus balticus*), and tufted hairgrass (*Deschampsia cespitosa*) are also a prevalent species in slightly drier areas of riparian habitats of southeastern Idaho (Youngblood et al 1985, Padgett et al. 1989) and likely occurred historically. Poorly drained soils along Camas, Beaver, and Warm creeks that supported riparian herbaceous marshes include the Medano, Medano-Psammaquents, and Levelton-Medano complexes.

In addition to poorly drained alluvial soils along the creek channels, short emergent marshes also occurred in depressions on relict lakebeds from pluvial Lake Terreton and along the edges of semi-permanently flooded wetlands. Soil types mapped as short emergent marsh included Levelton-Medano and Medano complexes. The vegetation community was likely dominated by sedges similar to that described for riparian herbaceous marshes.

Semi-permanently flooded emergent wetland habitats occurred immediately upstream of and at Rays Lake where depth and duration of surface water flooding was higher as a result of "pinch points" in the stream channel. The ponding of water created by these pinch points allowed fine textured sediment to drop out of suspension, which resulted in development of Fluvaquent soils with very poor drainage. Semi-permanently flooded emergent wetlands occurred on these very poorly drained Fluvaquent soils. Areas of open water as mapped by NRCS were also assumed to be very poorly drained soils and mapped as semi-permanently flooded (with the exception of Sandhole Lake described below). However, without knowing the characteristics of the soils under areas mapped as open water, this may over-represent this historical extent of semi-permanently flooded wetlands. A high degree of variation in water permanence likely occurred in these wetlands. For example, some areas may have remained flooded during years with average or slightly above average precipitation (e.g., $0 < \text{PDHI} > 2$). Other areas may have only remained flooded during "very wet" or "extremely wet" periods (e.g. $\text{PDHI} > 3$), and, therefore, may have only been flooded for two to seven years during any 15-20 year wet period, but not flooded at all or for only very short time periods during drought years. During 1884, Rays Lake was mapped as a dry lakebed approximately 0.5 miles long with willows along the edge (McCoy 1884a).

This highly dynamic hydrology in an arid environment likely caused substantial shifts in vegetation in semi-permanently flooded wetlands. Vegetation likely transitioned from hardstem bulrush (*Schoenoplectus acutus*), three-square (*S. pungens*), common sprikerush (*Eleocharis palustris*), and pioneering submerged aquatic vegetation (e.g., sago pondweed, mare's tail [*Hipparus vulgaris*]) during wet years to sedges (*Carex* sp.) and less robust rushes (*S. pumilus*, *Eleocharis* sp.) during average years, and to species less tolerant of flooding (e.g., *Juncus* sp.) or mud flats during dry years (e.g., dry lakebed at Rays Lake during 1884). Cattails (*Typha* sp.), if present at all, likely represented only a minor component of historical semi-permanently flooded habitats. Slenderbeaked sedge (*C. athrostachya*) is often present along high water lines of ephemeral pools or reservoirs in the Intermountain West (Hurd et al. 1998) and likely occurred at CNWR. During multi-year droughts, these habitats may have resembled seasonal or temporary flooded wetlands. During years when the water table was high, Mud Lake and the adjacent sloughs had "luxuriant growths of marsh grass and tules" (Stearns et al. 1939:8).

Permanently flooded or nearly permanently flooded wetlands within CNWR occurred at Sandhole Lake, with open water areas likely dominated by submerged aquatic vegetation such as sago pondweed (*Stuckenia pectinata*) and other pondweeds (*Potamogeton* sp.), widgeon grass (*Ruppia* sp.), slender naiad (*Najas flexilis*), and milfoil (*Myriophyllum* sp.). Although no hydrologic descriptions are available for CNWR, water levels likely fluctuated as described for Mud Lake. Based on GLO maps, the area of permanently flooded habitats was annually variable. The mapped extent of open water (Fig. 23) is likely indicative of a wet period and would be much smaller during a dry period. During October 1881, Sandhole Lake is shown as two ponds in T7N R36E (Fig. 19) (David 1881b). During October 1884, when the interior township was surveyed and subdivided, Sandhole Lake is mapped as a slough, 9.3 chains (614 feet) wide tapering to a wash to the west and north of Rays Lake (Fig. 20) (McCoy 1884a). This spatial and temporal variation in permanently flooded conditions would have created an interspersion of robust emergent vegetation within the open water/submerged aquatic vegetation. During dry years, water in at least some portion of Sandhole Lake was likely maintained by groundwater discharge. Compared to higher elevation permanently flooded wetlands and lakes in the Rocky Mountains, Sandhole Lake likely had high productivity resulting from increased nutrient availability (Windell et al. 1986).

Willows (*Salix* sp.) and other shrubs occurred along one of the lost rivers during October 1835 (Haines 1965); however, willows are not included in accounts of early travels along Camas Creek or its tributaries, nor are they mentioned during GLO surveys of Camas Creek in the vicinity of CNWR, except for an area east of Rays Lake. Native willow species that may have occurred in the vicinity of Rays Lake include coyote willow (*S. exigua*), Pacific willow (*S. lasiandra*), and peachleaf willow (*S. amygdaloides*) (J. Chris Hoag, riparian plant ecologist, personal communication).

Wet meadow habitats occurred on poorly drained Levelton loamy sand soils. Wet meadow habitats were temporarily flooded, likely higher in elevation and adjacent to seasonal and semi-permanently flooded wetlands. These areas were likely groundwater flow-through systems or had enough precipitation or surface water inputs to prevent accumulation of salts found in saline meadows. Vegetation characteristic of wet meadows included Baltic rush, tufted hairgrass, clustered field sedge, and beaked sedge (*C. rostrata*).

Alkali/saline wet meadows occurred on poorly drained Levelton loam and moderately well drained Montlid-Heiseton soils. Alkaline and saline soils are common in pluvial lake basins in arid and semi-arid environments. These soils form when dissolved ions translocated by water are concentrated through evapotranspiration that exceeds precipitation (Boettinger and Richardson 2001). Groundwater discharge is often present in alkaline or saline soils. Vegetation characteristic of alkali/saline wet meadows included inland saltgrass, foxtail barley (*Hordeum jubatum*), Douglas sedge (*Carex douglasii*), clustered field sedge (*C. praegracilis*), alkali sacaton, Baltic rush, and squirreltail (*Elymus elymoides*).

Key Animal Communities

The wetlands and uplands of the ESRP supported a diversity of wildlife, including ungulates and other mammals, waterfowl, shorebirds, passerines, fish, amphibians, and reptiles (Appendix B). Buffalo (*Bison bison*) were common and numerous on the ESRP during the early-1800s. During the 1820s, Peter Ogden described the ESRP from Birch Creek as "covered with buffalo" (Wessink 1986). Trapper Russell Osborne traveled south along Camas Creek "amid thousands of Buffaloe [sic]" during late September 1835 (Haines 1965:34). Large bands of buffalo and wolves were observed south of "Camas Lake" (probably Mud Lake), and were described as "feeding in immense bands…all over the plain as far as the eye could see" (Haines 1965:36). Buffalo observed during the fall on the ESRP were apparently in good body condition, whereas those observed during May were described to be in poor condition. Numerous herds of deer (*Odocoileus* sp.) and "superabundant" waterfowl were described by Alexander Ross as he traveled across southern Idaho during 1824 (Wessink 1986).

Other game of the ESRP mentioned in early accounts (e.g., Anderson 1940, Haines 1965) included bighorn sheep (*Ovis canadensis*), pronghorn (*Antilocapra americana*), and rabbits. Russell (1902) reported that pronghorn lived on the ESRP year round and that deer and elk (*Cervus elaphus*) used the area as winter range. Other mammals commonly observed included bears (*Ursus* sp.), wolves (*Canis lupus*), lynx (*Lynx canadensis*), badgers (*Taxidea* *taxus*), coyotes (*Canis latrans*), foxes (*Vulpes* sp.), and skunks (*Mephitis mephitis*).

Other species on the ESRP were not described until the late-1800s. Small mammals included sage or Great Basin chipmunks (*Tamias* sp.), Townsend's ground squirrels (*Spermophilus townsendii*), Ord's kangaroo rats (*Dipodomys ordii*), northern grasshopper mice (*Onychomys leucogaster*), pocket mice (*Perognathus* sp.), pigmy rabbits (*Brachylagus idahoensis*), black-tailed jack rabbits (*Lepus californicus*), white-tailed jackrabbits (*L. townsendii*), and Nuttail's cottontails (*Sylvilagus nuttallii*) (Merriam 1891).

Fish, including trout (*Oncorhynchus* sp.) were abundant in Birch Creek and the Lost rivers (Anderson 1940) and may have occurred in Camas and Beaver creeks. Fish species could have been transported to different drainages by early settlers (Gamett 2009), but it is likely that Yellowstone cutthroat trout (*Oncorhynchus clarkia bouvieri*), mountain whitefish (*Prosopium williamsoni*), Paiute sculpin (*Cottus bledingi*), shorthead sculpin (*C. confuses*), and mottled scuplin (*C. bairdi*) were native to at least some of the lost river drainages. Rainbow trout (*O. mykiss*) and bull trout (*Salvelinus confluentus*) may have also been native to some of these streams, but the status is currently unresolved (Van Kirk et al. 2003, Gamett 2009).

Birds characteristic of the sagebrush steppe of the ESRP included sage sparrows (*Amphispiza belli*), brewer's sparrows (*Spizella breweri*), sage thrashers (*Oreoscoptes montanus*), burrowing owls (*Athene cunicularia*), sage grouse (*Centrocercus urophasianus*), sharp-tailed grouse (*Tympanuchus phasianellus*), ravens (*Corvus corax*), and magpies (*Pica hudsonia*) (Merriam 1891). Sharp-tailed grouse were rare, but Stearns et al. (1939:7) stated that sage grouse occurred "in large numbers, and in the winter flocks of several hundred may be seen." Up to an estimated 2000 sage grouse occurred on CNWR during the fall and 800 to 1,000 sage grouse wintered on the refuge well into January during the late-1930s. Sage grouse also nested on or near CNWR; young broods were observed on the refuge during April 1939 (USFWS refuge annual narratives).

The ESRP likely provided important spring migration and, during wet years, breeding habitat for migratory waterbirds in the Pacific Flyway. Ducks, geese, and other waterbirds visited the "ponds and streams, particularly along [the] Snake River and on the west side of the plain in the Lost River country" (Russell 1902:24). Mud Lake was known for its waterfowl hunting and a special train was sidetracked to the lake from Hamer during the 1920s (Stearns et al. 1939). Tundra swans (*Cygnus columbianus*), snow geese (*Chen caerulescens*), green-winged teal (*Anas crecca*), canvasback (*Aythya valisineria*), buffleheads (*Bucephala albeola*), and common goldeneyes (*Bucephala clangula*) are not common during summer months, but use habitats at CNWR during spring migration and were likely common during Presettlement times. Waterfowl species common at CNWR during the spring and summer that likely occurred historically include trumpeter swans (*C. buccinator*), Canada geese (*Branta canadensis*), gadwall (*Anas strepera*), mallard (*A. platyrhynchos*), American wigeon (*A. americana*), northern shoveler (*A. clypeata*), northern pintail (*A. acuta*), cinnamon teal (*A. cyanoptera*), ruddy duck (*Oxyura jamaicensis*), redhead (*Aythya americana*), and lesser scaup (*A. affinis*). Twenty-seven species of shorebirds presently occur at CNWR and likely occurred historically. The most common species during spring and summer include killdeer (*Charadrius vociferus*), American avocet (*Recurvirostra americana*), willet (*Tringa semipalmata*), long-billed curlew (*Numenius americanus*), Wilson's snipe (*Gallinago delicata*), and Wilson's phalarope (*Phalaropus tricolor*).

Reptiles on the ESRP noted by Merriam (1891) include rattlesnakes (*Crotalus* sp.), short-horned lizards (*Phrynosoma douglasii*), sagebrush lizards (*Sceloporus graciosus*), and bull snakes (*Pituophis catenifer*). Mole crickets (*Gryllotalpa* sp.) were also noted as common during the fall. Aquatic invertebrates found in the lost streams of Idaho include mayflies, stoneflies, caddisflies, dipterans, beetles, mollusks (Andrews and Minshall 1979). Nine species of dragonflies and 33 species of butterflies occur at CNWR.

Muskrats (*Ondatra zibethicus*), beaver (*Castor canadensis*), and river otters (*Lontra canadensis*), although not mentioned in early account of the lost river basins, likely dispersed to CNWR at least during wet years as indicated by early population estimates. During the 1930s and 1940s, the populations of muskrats at CNWR fluctuated between an estimated 30 to 10,000 individuals.

CHANGES TO THE CAMAS ECOSYSTEM

OVERVIEW

To evaluate changes to the ESRP and CNWR, this study obtained information on contemporary: 1) physical features, 2) land use and management, 3) hydrology and water quality, 4) vegetation communities, and 5) fish and wildlife populations of CNWR. These data chronicle the history of land and ecosystem changes at and near the refuge compared to the Pre-settlement period and provide perspective on when, how, and why alterations have occurred to ecological processes in CNWR and its surrounding lands. Data on chronological changes in physical features and land use/management of the region are most available and complete (e.g., GLO maps and survey notes, USFWS refuge annual narratives, USDA and USGS records, aerial photographs, historical maps); whereas, data documenting changes in fish and wildlife populations generally are limited to qualitative descriptions in historical accounts and population estimates in the USFWS refuge annual narratives.

EARLY SETTLEMENT AND LAND USE CHANGES

Archeological evidence indicates that humans have occupied the Snake River Plain for at least 15,000 years. Pre-recorded history for the CNWR area is summarized in the draft CCP (USFWS 2014) based largely on information from Harding (2005). Pre-historical big game hunters followed big game animals such as mammoth, horse, and camel. As spear points evolved from 12,000 to 7,500 years before the present (BP), hunting shifted to archaic bison (*Bison antiquus*), followed by modern bison, and bighorn sheep. From 7,500 to 1,500 BP, resource use expanded to include small game mammals and plants in addition to bison and other large game.

Native Americans in southeastern Idaho included the Northern Shoshone and Northern Paiute (Bannock). They lived in groups composed of highly mobile nuclear families or family clusters, egalitarian in nature, who practiced wide-spectrum subsistence activities (summarized by USFWS 2014). The general subsistence pattern consisted of seasonal visits to areas where particular resources were abundant. Spring and summer were characterized by hunting, fishing, and gathering. Fish were primarily exploited in the spring, when the stores of bison meat ran low. Autumn was characterized by a move to the mountains to gather pinyon and other pine nuts, and in some areas, acorns. Winter was spent at low elevation camps along drainages.

The horse and European trade goods were introduced into the Snake River Plain region as early as 300 years BP. After acquisition of the horse, resources were more efficiently exploited and the Shoshone and Bannock people developed winter village sites around the Fort Hall bottoms of the Snake River, which is south and west of the CNWR. They were likely frequent travelers through the present-day CNWR as they went to the meadows near Kilgore, Idaho to gather the roots of camas. Members of the Nez Perce, Flathead, Crow, and Blackfeet tribes regularly passed through the region as part of their subsistence traditions, to trade, and/or to attack resident tribes.

The Lewis and Clark Expedition passed less than 100 miles north of the refuge and the first European settlers arrived shortly thereafter. The nineteenth century brought huge transformations in the subsistence cycle and lifestyle traditions of the Shoshone and Bannock people when the area around

CNWR was first settled by trappers, traders, and missionaries. The first American trading post on the Pacific slope was erected at Egin, Idaho during 1810, but it was soon abandoned (Stearns et al. 1939). Early settlers constructed homesteads, small irrigation ditches, and wagon roads in and near CWNR. One homestead was mapped within CNWR during 1881 (David 1881b).

During the mid-1800s, gold was discovered in Montana and a wagon and stage road, which extended from Salt Lake City, Utah to Butte, Montana, was constructed across the Snake River Plain through the present-day CNWR. Exploring parties of the Pacific Railroad Surveys passed through Idaho from 1853 to 1857. The Utah and Northern Rail Road was constructed along the eastern edge of CNWR and reached Butte, Montana during 1881 (Strack 2011). During 1870, a stage stop station was established at Sandhole Lake (Stearns et al. 1939).

The Oregon Trail emigrants, miners, and railroad construction crews increased the competition for natural resources that the Shoshone and Bannock had relied on for hundreds of years (USFWS 2014). As early as 1834, trapper Warren Ferris noted beaver and other game animals were becoming rare and predicted that a herd of bison would be a rare sight by the mid-1840s (Wessink 1986). This prediction held true when both Osborn Russell and John Fremont wrote during 1841-1843 that the only traces of previously abundant bison were scattered bones and an occasional skull. Previously abundant pronghorn were still present on the ESRP, but in much lower numbers (Wessink 1986).

In the upper Columbia River basin, beaver populations declined drastically from 1835 to 1850 as a result of over harvest (Johnson and Chance 1974). The near removal of beaver prior to most historical accounts of the area likely decreased alluvial sedimentation rates in valley bottom streams, increased stream channel incision and erosion, and modified biogeochemical characteristics (Baker and Hill 2003).

Following the discovery of gold, wildlife populations were further reduced by market hunters, who supplied camps of miners, prospectors, and railroad workers in southern and central Idaho with large numbers of deer, elk, waterfowl, salmon, and cutthroat trout. Market hunting nearly eliminated some deer herds in western and central Idaho. By 1914, Idaho Department of Fish and Game reported only a few scattered bands of elk in eastern Idaho (Wessink 1986). Market hunting also had a substantial impact on waterfowl nearly eliminating trumpeter swans from the lower 48 states, except in the Greater Yellowstone Area of Idaho, Montana, and Wyoming (Banko 1960, Mitchell and Eichholz 2010).

REGIONAL LAND USE AND HYDROLOGIC CHANGES SINCE 1880

Substantial land use changes on the ESRP started in the late-1800s and steadily increased during the early 20th century. Legislation passed by Congress, including the Carey Act of 1894 and the Reclamation Act of 1902, resulted in significant expansion of agriculture throughout southeast Idaho (Goodell 1988). Under the Carey Act, the state of Idaho received 618,000 acres of arid desert lands for cultivation, including substantial tracts of land in and around the present day CNWR (USFWS 2014). Idaho's population nearly doubled from 1900 to 1910, increasing from 164,000 to 325,000 people. The primary alterations to the lands at and near the present-day CNWR include the following:

- Degraded riparian corridors due to domestic livestock grazing, especially sheep, and diversion of stream flows.
- Altered hydrology due to development of ground and surface water resources for irrigation.
- Altered topography, including many roads, dikes, ditches, borrow areas and water delivery infrastructure for irrigation.
- Conversion of sagebrush steppe, native meadows and sand dunes to grazing pasture and cultivated croplands.

Irrigation on the ESRP began about 1880; almost 40 years after irrigation began on the western Snake River Plain. Small, local projects were concentrated initially on lands adjacent to rivers or within a short distance of canals (Goodell 1988). Livestock and ranching operations (including grazing and haying) began during the late-1880s in the Mud Lake region when ranches became established along Camas, Beaver, and Medicine Lodge creeks (Stearns et al. 1939). By 1899, Newell (1903) reported that irrigation on the entire Snake River Plain had increased to 550,000 acres, an increase of more than 100% over the previous 10 years. Irrigated acres in the ESRP during 1899 occurred along the Snake River, the Rigby Fan southeast of CNWR, the Egin Bench, and in a small area along Camas Creek about 13 miles north of CNWR (Goodell 1988).

Tens of thousands of domestic sheep were driven to and grazed on "withered grasses and nutritious shrubs" on the Snake River Plain during the winter months (Russell 1902). In the counties of Idaho that include portions of the Snake River Plain, it was estimated that over 1 million sheep, nearly 200,000 cattle, and about 34,000 horses used the sagebrush plains as winter pasture (Russell 1902). "The area of these natural pastures is so great, however, that but little damage has as yet been done, except in the neighborhood of the streams which flow down from the mountains" (Russell 1902:23). Although not described by Russell, early grazing of domestic livestock likely started to alter species composition of sagebrush steppe habitats and increase the cover of sagebrush, contributing to "decadent" sagebrush steppe communities.

Soil erosion, which correlated with the introduction of sheep grazing as described by Russell (1902) for small valleys in the western Snake River Plain, is one of the earliest examples of how the downcutting of water drainages through the substrate affected the ability of surrounding lands to hold surface and subsurface water. These eroded and incised channels dried out luxuriant meadows of wild grasses and resulted in complete sub-drainage of many fields in cultivated areas, requiring more irrigation (Russell 1902).

Early irrigation efforts primarily supported livestock operations and then increased as cultivated crops expanded. By 1929, irrigated land on the entire Snake River Plain had increased to 2.2 million acres, including land south and west of Mud Lake and additional areas along Camas Creek and the Egin Bench (Goodell 1988). Surface-water irrigated acres remained relatively stable due to low crop prices during the depression and World War II (Goodell 1988); only an additional 0.3 million acres were irrigated from 1929 to 1945. Diversion of surface water for irrigation reduced the quantity of water in stream corridors and riparian habitats, altered subsurface hydrology where ditches were constructed, and increased recharge to the regional ESRP aquifer.

Approximately 288,000 acre-feet was diverted May-September each year from 1919 to 1932 for irrigation and an estimated 88,300 acre-feet was diverted outside of the irrigation season. Flood irrigation of fields during the early 20th century was not efficient. Therefore, when water was applied on the well-drained sandy loam soils, most of the water infiltrated into the aquifer (USFWS 2012). Alluvium on the Egin Bench was very permeable; therefore, fields were irrigated by running water down lateral ditches until the water table was raised to the desired height through percolation from these laterals.

Irrigation water applied to fields on the Egin Bench infiltrated through the alluvium and moved south to the Henrys Fork and west-northwest to the vicinity of CNWR (Stearns et al. 1939). The increase in groundwater discharge from springs observed during the early 20th century has been attributed to recharge from irrigation on the Egin Bench (Stearns et al. 1939, USFWS 2012). Also coincident with increased surface water irrigation from 1890 to 1952, the regional aquifer storage increased by 24 million acre-feet, corresponding to an average rise in the water table of approximately 50 feet (Goodell 1988). Although increased surface water irrigation significantly contributed to the increasing water table, an 18-year wet period occurred from 1906 to 1923 (NOAA 2013) with 1915 being the central point of one of the 4 wettest epochs in the western United States during the past 1,200 years (Cook et al. 2004). As modeled for recent conditions (1980-2008), changes in precipitation closely corresponded to changes in aquifer recharge (Fig. 25) (IDWR 2013). Therefore, increased precipitation and the subsequent increased spring runoff and streamflow during 1906-1923 also would have contributed to increased groundwater recharge, but this has not been modeled for historical conditions.

Due in part to the shallow alluvial aquifer overlying the regional aquifer, the Mud Lake area was one of the first regions in the ESRP to develop groundwater resources for irrigation (Goodell 1988). Fifteen wells with artesian flow were drilled near Hamer by 1928 and discharged 1,200 acre-feet monthly (Stearns et al. 1939). Groundwater pumping in the Mud Lake area increased steadily after 1945 when groundwater became an important source of irrigation water throughout the ESRP. Irrigated acres during 1966 had expanded to additional areas south and west of Mud Lake and additional areas along Camas and Beaver creeks (Goodell 1988).

Groundwater development increased rapidly during the 1950s and 1960s. By 1966, about 700,000 acres on the Snake River Plain were irrigated with

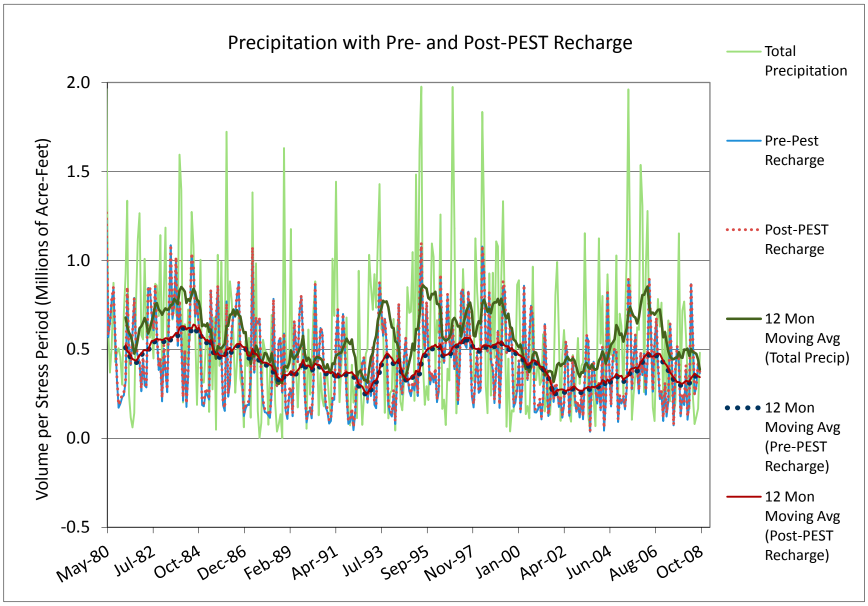

Figure 25. Net aquifer recharge in comparison with precipitation for the transient Enhanced Snake Plain Aquifer Model, version 2.1. Stress periods are each month included in the aquifer model; pre- and post-PEST refers to before and after model calibration. From IDWR (2013).

groundwater, including additional acres to the west and northwest of Mud Lake; 2.5 million acres continued to be irrigated by surface water (Goodell 1988). Center-pivot irrigation was developed on lands east and south of the CNWR sometime after 1963 (Fig. 26). Discharge from irrigation wells on the Snake River Plain ranges from 269 to 6,820 gallons per minute (Graham and Campbell 1981).

An estimated 3.1 million acres of the Snake River Plain were irrigated during 1980, requiring 15 million acre-feet of water. Of these lands, 2 million acres were irrigated with 12.7 million acre-feet of surface water mostly conveyed through 2,700 miles of canals and lateral ditches, 1 million acres were irrigated with 2.3 million acre-feet of groundwater, and the remaining 0.1 million acres were irrigated by a combination of both water sources (Goodell 1988). Eighty four percent of the total groundwater pumping for irrigation on the Snake River Plain occurred on the ESRP. The Mud Lake region has the highest groundwater pumping, estimated at >500 acre-feet/square mile during 1980 (Goodell 1988). Total annual withdrawal from the ESRP aquifer in the Mud Lake area increased from 240,000 acre-feet during 1983 to 370,000 acre-feet during 1990 (Spinazola 1994a). Major crops on the ESRP during 1980 included small grains, hay, pasture, potatoes, and sugar beets.

Aquifer recharge from surface water irrigation started to decline in the 1950s as groundwater pumping increased and water distribution became more efficient (Goodell 1988). During 1980, percolation of surface-water irrigation accounted 4.84 million acre-feet of total aquifer recharge (Garabedian 1992). Surface water irrigation recharge since then has averaged 2.4 million acre-feet (IDWR 2013).

Pumping of groundwater from the regional ESRP aquifer has lowered the water table at CNWR and surrounding lands and resulted in a cumulative decrease in aquifer storage of about 3% (USFWS 2012). Approximately half of the 43 ground water wells in the USGS active groundwater level network in Jefferson County are ranked as below normal, much below normal, or low groundwater level (USGS Groundwater Watch, http://groundwaterwatch.usgs.gov/) (Fig. 27). Similarly, the water table at most wells within CNWR has decreased since the 1970s. For example, the water table at well #1 decreased approximately 15 feet from 1973 to 2007 (Fig. 28) (Heck 2008). This decline is comparable to several wells in the Idaho Dept. of Water Resources database (http://www.idwr.idaho.gov/hydro.online/gwl/default.html).

Refuge Establishment and Management History

CNWR was established through Executive Order 7720 on October 12, 1937 with the primary purpose "as a refuge and breeding ground for migratory birds and other wildlife." When CNWR was established, surface water diversions, ditches, roads, and small tracts of cultivated grains had been developed by early settlers. A landcover map from 1937 shows areas within CNWR classified according to agriculture and grazing value (Fig. 21). Although straight line fields are evident from the land cover map, most areas mapped reflected the natural boundaries of native habitats (see Fig. 23). For example, areas classified as low value for grazing were areas where historical vegetation was mapped as sagebrush steppe or salt desert shrub/grassland

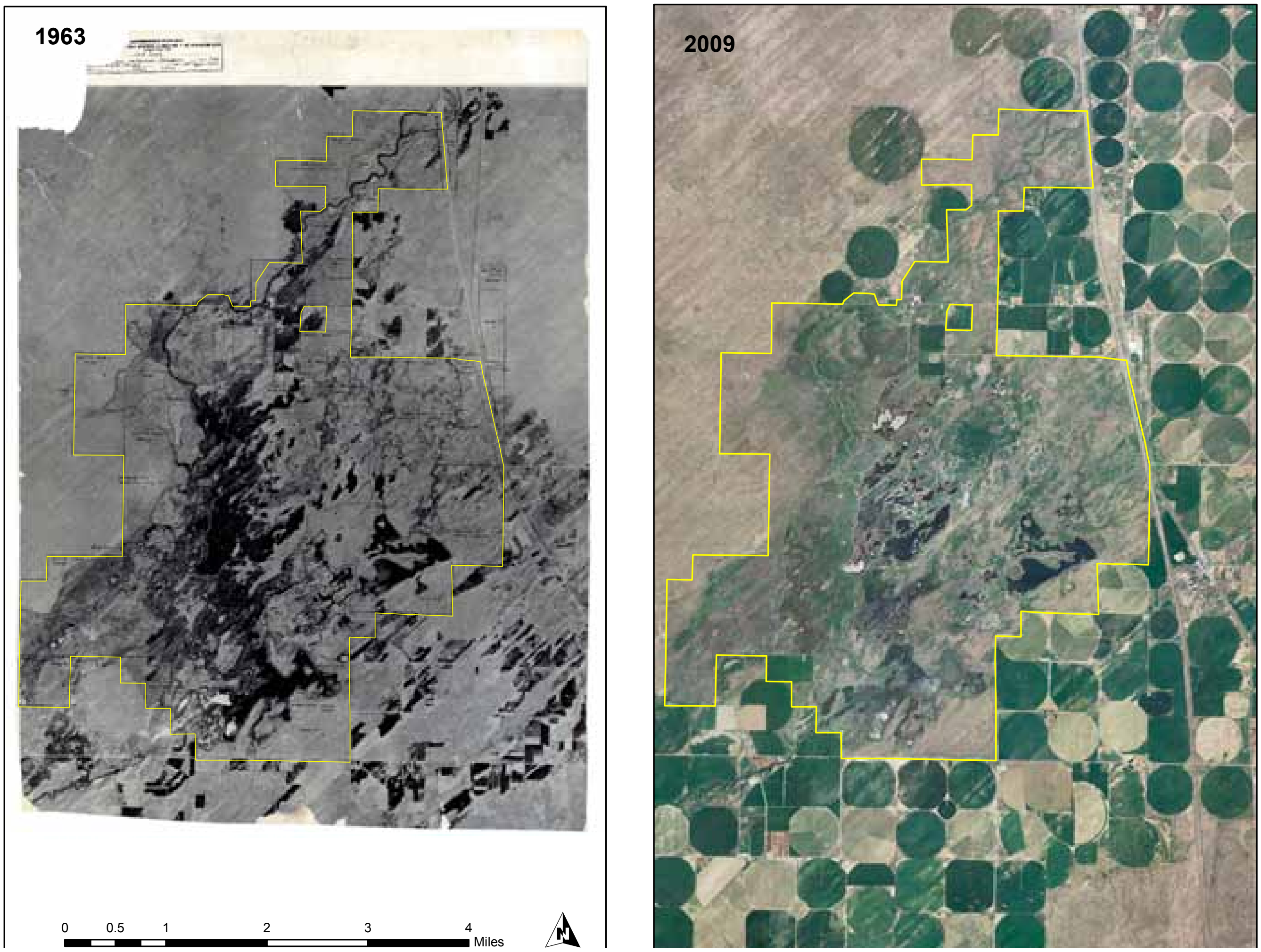

Figure 26. Aerial imagery of Camas National Wildlife Refuge and surrounding lands during 1963 (from USFWS) and 2009. From refuge office files and USDA Geospatial Data Gateway (http://datagateway.nrcs.usda.gov/).

according to soil type (this study). Although irrigation practices contributed to a higher than natural groundwater level and may have killed sagebrush in some areas, hay lands during 1937 occurred on the more poorly drained soils suggesting this was the historical vegetation community. Some hay lands had been drilled with redtop, clover, and/or timothy to improve forage production (1929 Supplemental Report to Accompany Idaho Live Stock Lands Inc.).

Water management at CNWR (and other refuges established during this time period) sought to "drought-proof" wetland areas and sustain waterfowl populations (Sanderson 1980). Although these motivations promoted wetland protection and management across North America, they resulted in extensive physical development and alterations to topography and water flow patterns. Management of more consistent, stable, and deep water regimes ultimately compromised the long-term sustainability and productivity of wetland systems (e.g., Weller 1994).

Early development actions in the late-1930s by USFWS focused on improving existing infrastructure originally designed for irrigation and included cleaning and repairing ditches, rebuilding and extending dikes, and installing water-control structures. During the 1940s and 1950s, development of water-control infrastructure for wetland habitats increased (Table 3). Specifically, ditches, berms, and water-control structures were built or rehabilitated to: 1) maintain higher water levels in ponds; 2) move water to wetland impoundments that often dried before broods fledged; 3) allow for maximum diversion of Camas Creek water rights; 4) reduce flood damage; and 5) "keep Camas Creek in its channel" (USFWS refuge annual narratives).

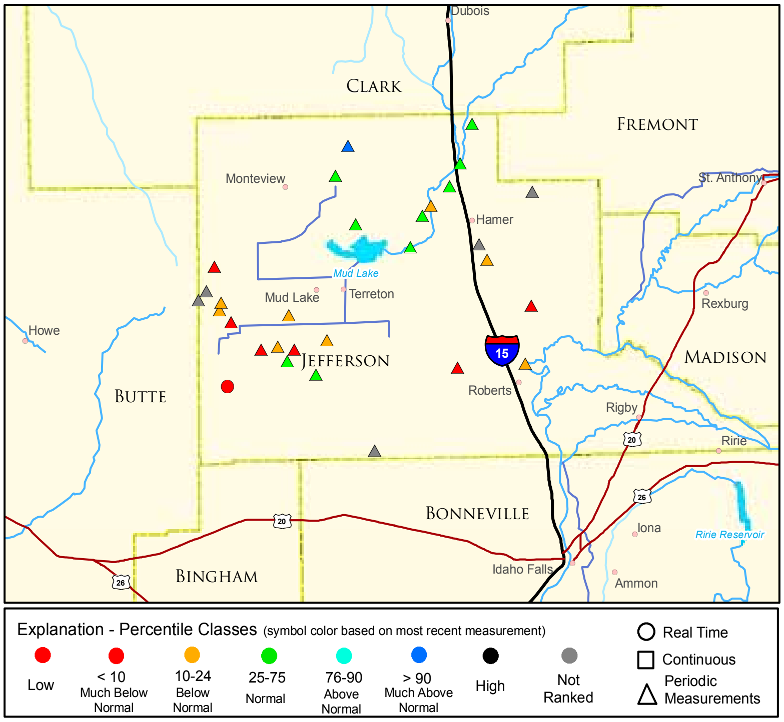

Figure 27. Classification of groundwater levels at 43 wells in Jefferson County, Idaho. From USGS Groundwater Watch (http://groundwaterwatch.usgs.gov/, accessed June 2012).

Early habitat management actions included seeding wild millet, bulrush, sago pondweed, floating-leaf pondweed (*Potamogeton natans*), wild celery, crested wheatgrass (*Agropyron cristatum*), a limited amount of native grass species, and other herbaceous plants beneficial to wildlife. Early efforts to establish crested wheatgrass were not successful unless the plantings could be irrigated during the spring. Bulrush and naiads were also transplanted throughout the refuge. Native and non-native shrubs and trees were planted as wind breaks, cover for upland game birds, and for dike protection. Woody vegetation planted included Siberian pea (*Caragana arborescens*), chokecherry (*Prunus virginiana*), hawthorne (*Crataegus* sp.), currant (*Ribes aureum*), black willow (*Salix nigra*), hybrid cottonwood (*Populus* sp.), wild plum (*Prunus americana*), and Russian olive (*Elaeagnus angustifolia*). Survival was highest for willow, Russian olive, and currant (USFWS refuge annual narratives).

Irrigation wells were installed during the 1950s and groundwater was used to supplement surface water flows from Camas Creek for management of wetland impoundments. Use of groundwater enabled filling of wetland impoundments even when surface water flows were low, resulting in longer and more stable hydroperiods in managed wetland units. In addition, groundwater use increased during the 1960s as new wetland units were built and existing impoundments rehabilitated.

In response to increasing abundance of cattails, control efforts started during 1954 when 605 acres were aerially sprayed with herbicide. The first prescribed burn was completed during 1960, but it was not effective at controlling cattail because it did not burn deep enough to kill roots. By the mid- to late-1960s, the use of prescribed burns and grazing to control cattail increased. Burning continues to be used as a tool to control cattail.

Water delivery infrastructure at the refuge currently includes 26 miles of dikes, 34 miles of ditches, nine bridges, 130 water-control structures, two point of diversions from Camas Creek, and nine groundwater wells (Fig. 29) (USFWS 2012). Wetlands and irrigated croplands at CNWR are managed in accordance with 37 certified water rights held by USFWS;

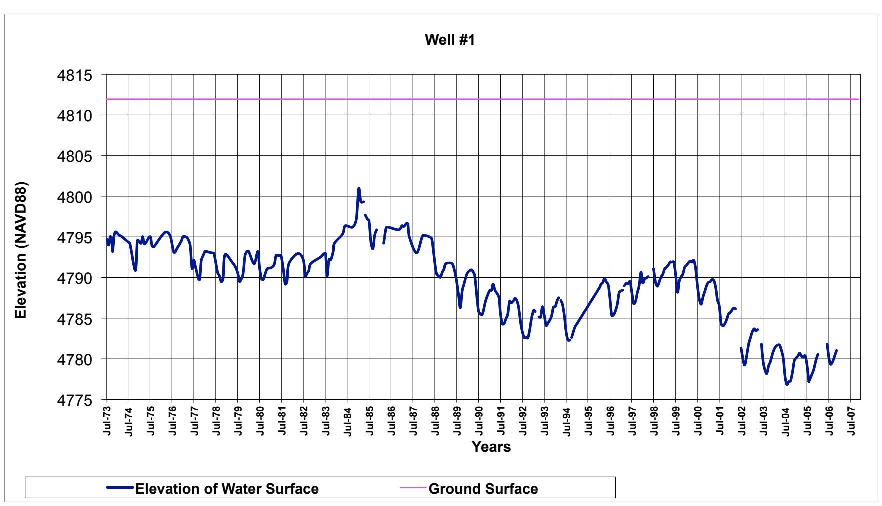

Figure 28. Elevation of water at Well #1 at Camas National Wildlife Refuge, 1973-2007. From Heck (2008).

Table 3. Chronology of developments at Camas National Wildlife Refuge. Summarized from USFWS refuge annual narratives.

Year	Wetland Development Activities
1937	Camas National Wildlife Refuge established as a "refuge and breeding ground for migratory birds and other wildlife."
1938	Extended and raised road grades 1) along the east side of Camas Creek in section 18 in T7N R36E and 2) dividing the pothole area (total raised roads = 6 miles).
	Pothole to pothole ditch system extended by 1.25 miles, two short spur dikes added, and four water control gates installed in outlets of key potholes; also rebuilt existing ditch banks.
	Constructed two rock and earth diversion structures, 75 small irrigation spill boxes, and 50 ditch headgates; cleaned 13 miles of ditches.
	Owsley canal company put a check dam in Camas Creek below Rays Lake to keep their water from backing up into Rays Lake. This prevented drainage of Rays Lake.
	New dike constructed to keep water out of neighbor's hayfield, 3 small dikes constructed to prevent water from overflowing into adjacent land not yet acquired, and one old dike strengthened.
	Razed 12 old buildings.
1939	Enlarged old ditches, constructed six new ditches, and built up several miles of old dikes/roads in Sections 7, 8, 17, 18, 19 in T7N R35E; dug new ditch to replace old Toomey Ditch.
	Roughed in road down west side of Camas Creek, enlarged dike roads through the pothole area.
	Built culvert in supply canal where road from the highway enters headquarters.
	Began work on permanent diversion structure for Toomey Ditch, but difficult excavation through muck, soft blue clay, and quick sand.
1940	Built headgate in Camas Creek (sw 1/4 of section 18, T7N R36E) for Toomey take-out (48" Calco gate in rubble culvert).
	Built 24" Calco gate in rubble culvert (section 28, T8N R36E).
	Built lower diversion headgate with bridges in Camas Creek just above Rays Lake (sw 1/4 of section 19, T7N R36E).
	Installed three rubble culverts (two with flashboards) in refuge ditch/road system; built various other culverts and water control structures.
	Raised two miles of road from 1 to 2 feet in sections 7, 17, & 18 in T7N R36E and raised an additional 6 miles throughout refuge.
	Enlarged 1/2 mile of pothole ditches, relocated 1.5 mile of ditch, riprapped 150 yards of ditch, and cleaned 3 miles of ditch.
1941	Constructed three bridges across Camas Creek, one bridge across Warm Creek, and various water control structures.
	Raised 1 mile of dike road 2 feet.
	Plowed 5 acres adjacent to headquarters and seeded to crested wheatgrass.
1943	Continued to raise dikes, including 1,100 yards of earth fill at south side of Two-way Pond.
	Constructed 1.25 mile of 3' ditch for cultivated lands north of headquarters.
	Weeds cleaned out of 2 miles of supply ditch several times.
1944	Constructed 2 miles of 3' ditch; widened and deepened pond connecting ditches.
	Flashboard box raised 2 feet to maintain higher water levels in Two-way Pond.
	Repaired roads washed out due to high water, wave action, heavy rains, and muskrats (required 7,500 cubic yards material). Opened up several borrow pits, but material unsuitable for roads.
	Rebuilt road around Toomey Pond.
1945	Added rock to rock check on Warm Creek.
	Built up stretch of Rat Pond road along west side of Pool 4-3 to hold about 18 inches higher water and expand the flooded area; built up portions of Center & Supply ditch roads using 3,000 yards of dirt.
	Built up earth plug in drain ditch below Pool 9-1 and dug small ditch into 2 potholes to create 6 acres of new flooded area.

Continued on next page

Table 3, continued.

Year	Wetland Development Activities
1946	Main diversion ditch in bad condition with banks crumbling and ditch bottom rising.
	Built 1/2 mile of emergency dike to prevent flooding to fields and raised other dikes for flood control (7,100 yards material).
	Constructed and repaired dikes to keep Camas Creek in its channel; raised and widened creek banks in many places.
	Cleaned Camas Creek to remove willows obstructing flow.
	Straightened banks of Camas Creek above headquarters and riprapped to protect piers of Camas Creek Bridge.
1947	Repaired break in Camas Creek north of refuge; new emergency spillway cut above structure 1A.
	Constructed two dikes 100 yards apart from Camas Creek south to reach old Warm Creek overflow channel.
	Replaced hand plugs in Units 8 & 9 with dirt and level of these units held 6 inches higher.
	Riprap placed at diversion #1.
	Raised and strengthened dike roads using a total of 18,080 cubic yards of dirt over 2 years (1946-1947).
1948	Installed culverts at east end of Rays Lake and in the Sandhole Lake road.
	Relocated road east of Rays Lake to take it out of the swamp, therefore making it possible to reach east side of refuge at any time of year.
	Rebuilt main supply ditch as part of Flood Damage Repair program.
	Built concrete spillway in south bank of Camas Creek near highway.
	Draglined 40,827 cubic yards material.
	Placed culvert for inverted siphon under Dry Creek to replace plume taken out by floodwaters.
1949	Rebuilt 6 bridges and cindered approaches.
	Built check dam across Camas Creek below highway at site of similar structure maintained when it was privately owned; installed 48" headgate on north side of creek to irrigate 300 acres of farmland that had reverted to grass.
1950	Rebuilt irrigation ditches, filled low spots along Camas Creek, riprapped ditch banks and Brindley Bridge, and enlarged 3 irrigation checks in main supply ditch.
	Broke ground on 160 acres of land to allow for rest-rotation of grain cultivation.
1951-52	Dynamited water holes in grazing units.
1953	Repaired break in Camas Creek with dragline and 6,000 yards of dirt.
	State department cleaned Warm Creek below highway where it had filled with sand 2 years prior during high water.
	Draglines finished flood damage work moving 10,000 cubic yards of dirt.
	Member of Independent Water Users dug a deep ditch outside of and parallel with the refuge for the purpose of draining even more water out from under the refuge at the south end and also dozed a ditch across a portion of the refuge where he was officially denied ROW.
1954	Raised dike below Center Pond 2 feet using dragline.
	Drilled large irrigation well 209 feet deep and in northeast corner of refuge to supply water for 300 acres.
	Deepened Bramwell well to 180 feet, dug ditch and laid pipe to connect with High Line Ditch.
	Ditch cleaning by operations by Independent Water Users in Unit 21 lowered water levels in nearby sloughs.
	Headgate and 4' culvert placed in Independent ditch to permit refuge to hold back water for a period each month.
	Riprapped 3 diversions in main supply ditch with 150 tons riprap.
1955	Raised grade on Toomey Road.
1956	Additional dikes dozed up in low spots to prevent damage to hay fields.
	Leveled 20 acres of land in Unit 1.
	Cleaned and redrilled well at Buck Springs.

Continued on next page

Table 3, continued.

Year	Wetland Development Activities
	Well drilled in Unit 4.
1957	Riprapped dikes at Toomey and Center ponds for road protection
	Installed 3 pumps on free-flowing wells and drilled 1 well at Buck Springs.
	Riprapped main supply ditch inlet.
1958	Placed 166 tons of riprap to strengthen stream bank and 72 yards of fill in road in Unit 1.
	Built dike around well #4 in case Camas Creek overflowed.
	Prepared wells #2, 3, 4, 5, & 6 for pumps, dug pipe line ditches, riprapped discharge pipes, dug holes and set service poles for all wells.
1959	Leveling improvements on 17 acres in Unit 1.
	Drilled new 36" well at Buck Springs.
	Widened 1.75 miles of Camas Creek to 30 feet.
1960-61	Constructed 13 miles of diversion ditches, able to carry 16 cubic feet/second, for wells #2, 3, 4, 5, & 6.
	Removed 10,080 cubic yards of soil from Camas Creek for well #3 diversion ditch.
	Constructed 500 yards of ditch in Unit 3 to maintain pond areas under well #3.
	Built 8 nesting islands in pond area fed by well #3.
	Completed water distribution system for wells #3 & 6; required 46,750 cubic yards of ditch fill for well #6 distribution system.
	Broke and leveled 30 acres of land adjacent to well #2 and 6 acres under well #3.
1962-64	Dynamited cattails at outlet of Big Pond; dynamited channels in marsh areas.
	Planted 43 acres of ditch banks with cheatgrass and crested wheatgrass and placed 300 cubic yards of riprap in well #6 ditches.
	Installed two 22" culverts to replace washed out wooden bridges south of Sandhole Lake.
	Constructed 800 feet of ditch with arch riser at Redhead Slough to control water levels
	Moved 17,500 cubic yards material repairing and building ditches; installed turnouts; and cleaned main supply ditch with dragline.
	Leveled 31 acres under well #4; leveled 41 acres in Unit 5 during 1963 and 21 acres during 1964.
	Developed water holes for livestock.
1965-69	Poured retaining wall at main diversion point.
	Installed water control structures and cleaned and repaired ditches.
	Leveled land on newly acquired Brown Ranch and 52 acres in Unit 1.
	Raised roads to protect cultivated crops in Unit 1 and raised road paralleling Camas Creek in Unit 1 and Unit 21.
	Cleaned 4 miles of Camas Creek with dragline and bulldozed 1 mile of willows.
	Erected plastic traps at diversion #1 so that more water would be diverted into refuge instead of wasted by flowing down the creek.
	Placed 280 yards rock riprap along Big Pond dikes.
1970	Leveled 38 acres and installed 17 irrigation turnout pipes on the Brown Tract.
	Raised 1/4 mile of ditch in Unit 21 to prevent flooding of private land.
	Built 12 nesting islands in Unit 21.
	Dragline and dozer used to clean excess willows, sand bars, old beaver dams, and other obstructions in Camas and Beaver creeks.
	Land leveling nearly complete, can efficiently irrigate 500 acres.

Continued on next page

Table 3, continued.

Year	Wetland Development Activities
1971-72	Constructed 1.5 mile canal to permit delivery of excess spring runoff to the eastern portion of refuge; this canal linked well #4 and Camas Creek to the distribution system under well #6.
	Main diversion sealed off with plastic to prevent water loss during summer months.
1975-76	Rebuilt main diversion structure on Camas Creek.
1977	Farming reduced from 358 acres to 143 acres.
	Built up dikes at Toomey and Redhead ponds.
	Replaced bridge across Warm Creek at Sandhole Lake with a 72'x8' corrugated metal pipe with a flashboard riser. This created 120 acres of new marsh habitat.
1978-79	Drilled new well and installed new water control structures to create new marsh on the east side of the refuge and improve delivery to central marsh units.
	Seeded 20 acres to dense nesting cover for a total of 346 acres converted.
1980-83	Constructed new dikes and rehabilitated dikes with dragline; cleaned canal between Center and Big ponds that had filled with cattails and silt; and built levee along County Road at headquarters.
	Removed old Brindley Bridge and installed water control structure.
	Constructed two new impoundments at north end of refuge.
	Installed sprinkler irrigation system.
	Replaced old control structure on Camas Creek near well #1 with bridge.
1984	Repaired roads following flood and wind damage.
1990	USDOT completed construction of I-15.
1995	Initiated marsh restoration project.
	Breached North Marsh Creek dike to restore natural floodplain.
	Raised levee on southeast side of Camas Creek upstream of main diversion by 1.5 feet.
	Mud Lake Water Users raised low spots around Mud Lake and built up Camas Creek bank.
	Negotiated conservation plan with Larson Farms to reduce erosion of Camas Creek through their property, which has resulted in significant silt accumulation in the refuge.
2002	Implemented wetland restoration actions with NAWCA grant funding.

two additional water rights held by USFWS are for domestic use (USFWS 2012). Each legal water right in Idaho has a point of diversion, point of use, rate of diversion, season of use, and must be applied to a beneficial use. Three privately held water rights have a point of diversion within CNWR and are used for irrigation outside of the approved refuge boundary. Water rights are summarized by Deutscher (2003) and USFWS (2012).

Most surface water used for wetland management at CNWR is diverted from Camas Creek through a radial gate/droplog structure at the north end of the refuge. This water is diverted into the Main Diversion Canal where water can flow into Big Pond, wet meadow units, Eastside Ditch, Main Canal Meadow Ditch, or Well 4 Fields Ditch. Water from Wells 2, 4, and 5 can also be pumped into the Main Diversion Canal (Fig. 30). The Westside Ditch is located to the west of Camas Creek and receives water from Well 3 and the Westside Diversion structure on Camas Creek. Diversions, wells, water delivery infrastructure and managed wetland units are detailed in a water management plan (Deutscher 2003).

The amount of surface water diverted from 1951 to 2011 ranged from 231 to 19,485 acre-feet (Fig. 31). During 1977 when diversion of surface water was 231 acre-feet, Camas Creek flowed at CNWR for only six days. During 1983 when 19,485 acre-feet was diverted, Camas Creek flowed almost the entire year. Groundwater pumping ranged from 3,000 to 14,000 acre-feet annually during 1959-1974 (Fig. 32). During 1995-2010, annual groundwater pumping ranged from 14,000 to 22,000 acre-feet. During 2011, the refuge only pumped 3,372 acre-feet of groundwater because high surface water flows provided ample water for management of refuge wetlands.

As recently as the early-2000s, wetland units at CNWR were managed for "average" conditions, with periodic drawdowns and flooding that mimicked dry and wet periods (Deutscher 2003). Management of wetland habitats extended from March through November to provide habitat for spring migration, nesting, brood-rearing, molting, and fall migration. When wetlands are dry during the winter, it takes several weeks to get sufficient water into the basins to provide habitat during spring migration (Deutscher 2003). Species targeted for management include dabbling ducks, diving ducks, colonial nesting waterbirds, swans, geese, sandhill cranes, wading birds, and shorebirds. No information on refuge water management in wetland units is available after 2003. The shelterbelt of planted cottonwood trees and understory shrubs has also been maintained and managed through irrigation, but many of the large cottonwood trees are dying with no natural germination. More native trees and shrubs were planted during 2005 and maintained with increased irrigation to replace the older trees. Irrigation of the planted shelterbelt reduces instream flows at Camas Creek and water available for native wetland restoration and management.

Haying, grazing, and cultivation of crops historically occurred on the refuge. Native habitats on a relatively small portion of the refuge were tilled and leveled for crop production. Crops were cultivated to provide forage for wildlife and to support waterfowl feeding programs on other refuges. For example, 3,600 pounds of clover was shipped to the National Bison Range and Nine Pipe National Wildlife Refuge and 1,000 pounds of alfalfa was shipped to Malheur National Wildlife Refuge during 1939. Share-cropping, where permittees harvested a portion of crops for agricultural purposes, and left the remaining proportion for wildlife, was also allowed on the refuge. The refuge farming program was reduced from 358 to 143 acres during 1977 when CNWR was no longer required to provide cereal grains to other refuges. Haying and cooperative farming (small grain and alfalfa) on the refuge continue to provide foraging habitat for

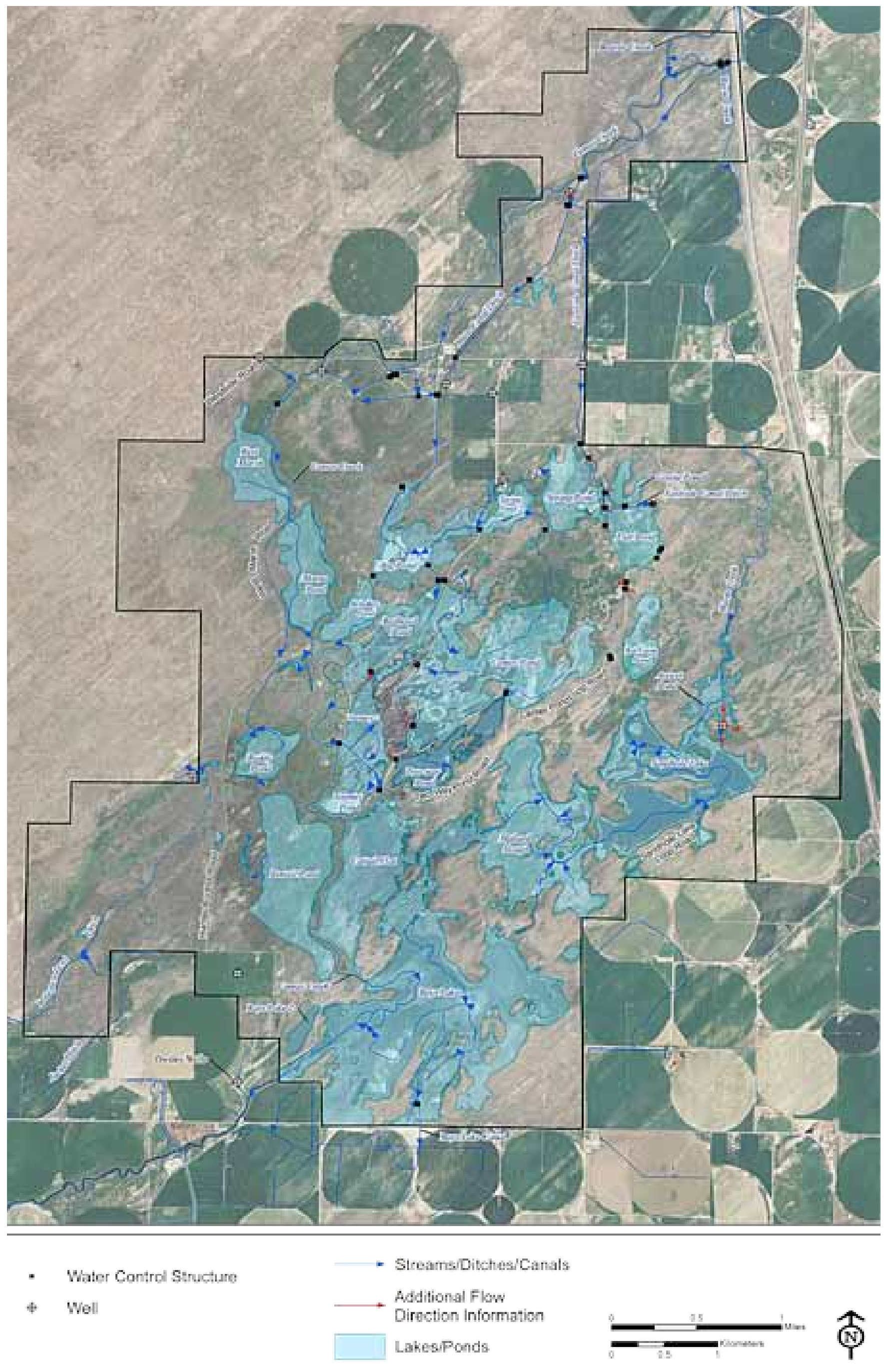

Figure 29. Wetland management areas and water-control infrastructure at Camas National Wildlife Refuge. From USFWS (2012).

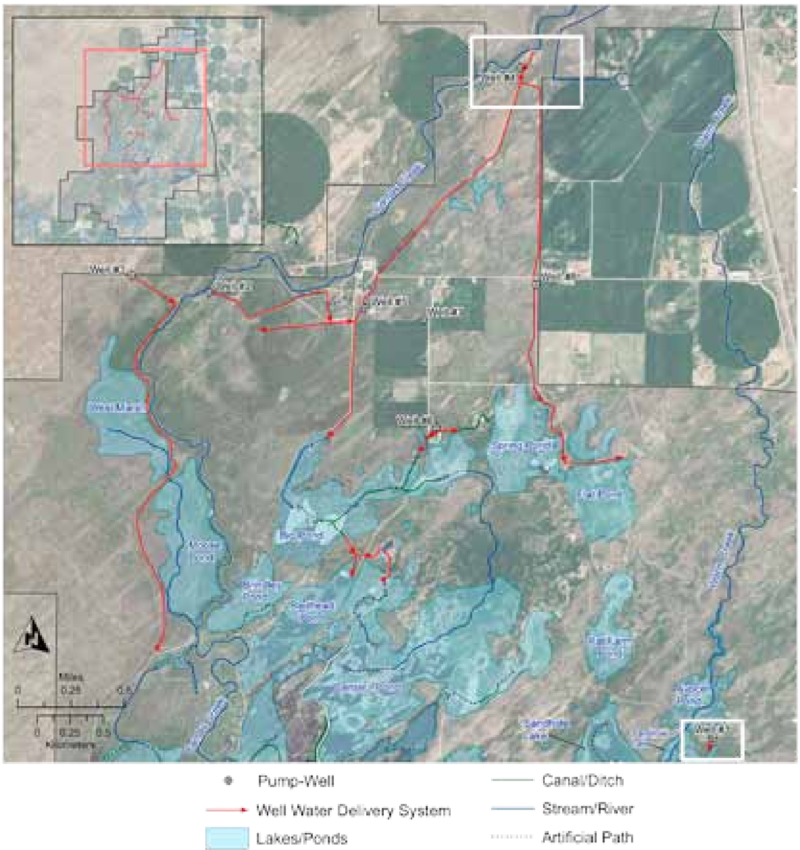

Figure 30. Well water delivery system showing main ditches at Camas National Wildlife Refuge. From USFWS (2012).

staging and migrating species such as Canada geese and sandhill cranes.

Winter hay feeding was terminated in 1969 as it was not beneficial to the refuge and may have been detrimental to range conditions during the spring (USFWS refuge annual narratives). Livestock grazing continued until it was determined to be incompatible with CNWR purposes during 1993. During the late-1980s approximately 2,500 to 3,500 animal use months (AUMs) were grazed on 3,000 acres. For the current draft CCP, grazing was considered but dismissed because it is not currently considered as a management tool needed to achieve refuge resource objectives (USFWS 2014).

The preferred management alternative for the CNWR draft CCP is to "provide a more diverse array of wetland, riparian, and upland habitats for not only waterfowl, but a variety of migratory birds and other wildlife" (USFWS 2014). Refuge management will focus on restoration and rehabilitation of wetland and riparian habitats over the next 15 years and will pursue restoration of upland habitat connectivity, function, and processes as additional funding and time allows. Based on the draft CCP (USFWS 2014), the planted shelterbelt habitat around headquarters will be managed for tall mature, naturalized cottonwoods and for native trees and shrubs within the understory; additional plantings to replace old cottonwood trees will be completed and irrigated as supplemental funding is secured.

CHANGES IN PLANT AND ANIMAL POPULATIONS

The major changes to plant and animal communities at and near CNWR include the following:

- Extirpation or significant reduction of some native animal species by the mid-1800s (described previously in this chapter);

- Decreased area and altered species composition of sagebrush steppe and native meadow habitats due to domestic livestock grazing, invasive species, altered fire regimes, and conversion to croplands;

- Altered wetland habitat due to subsurface soil drainage (e.g., ditches), localized water table changes in the shallow alluvial aquifer, and interactions with changes in the regional aquifer system;

- Altered stream corridors and riparian habitats due to livestock grazing, water diversions, land use practices in the Beaver-Camas subbasin, increased sedimentation, and planted woody riparian vegetation, including cottonwood trees and native and non-native shrubs;

- Increased extent of permanently flooded wetlands and decadence of semi-permanently flooded wetlands as a result of historical refuge management for more permanent and/or more stable water regimes in impoundments that continues to negatively impact nutrient cycling, productivity, and plant species composition; and

- Increased abundance and distribution of non-native invasive vegetation.

Few quantitative data are available to understand changes in plant and animal species abundance or distribution on CNWR. However, regional changes to native wildlife habitats in the Intermountain West and ESRP since European settlement are apparent at CNWR. Removal/reduction of Native American populations and their fire management practices, suppression of lightening caused wildfires, introduction of non-native species, grazing of domestic livestock (including sheep and cattle), and conversion of native habitats to croplands have altered, destroyed, or increased fragmentation of native habitats throughout the ESRP. Current habitat types at CNWR were mapped during 2011 (Fig. 33).

More than one half of the sagebrush habitat at CNWR has been highly degraded by altered fire regimes, livestock grazing, and invasive species (USFWS 2014). Shifts in native plant communities from bunchgrass-dominated to shrub-dominated occur as a result of preferential grazing by domestic livestock (Christensen and Johnson 1964) and likely occurred at CNWR by 1900. An area of rolling sand hills not grazed since refuge establishment supported excellent stands of needle and thread and Indian ricegrass with a few pockets of big sagebrush where a wildfire missed 15-20 years ago (USFWS 1983 refuge annual narrative). Low-intensity fire, an important factor in shaping the vegetation communities was practically eliminated by the late-1800s.

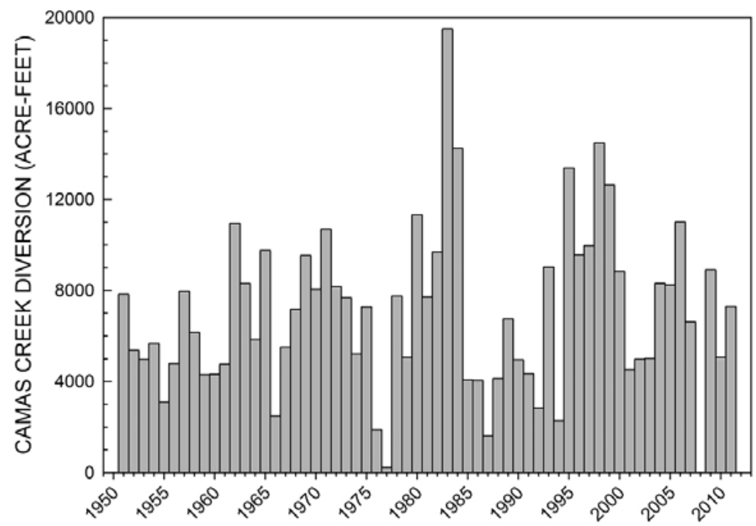

Figure 31. Surface water diverted from Camas Creek through the main and Westside diversions at Camas National Wildlife Refuge during 1951-2011. Zero = no data reported. Data compiled from USFWS refuge annual narratives and office files.

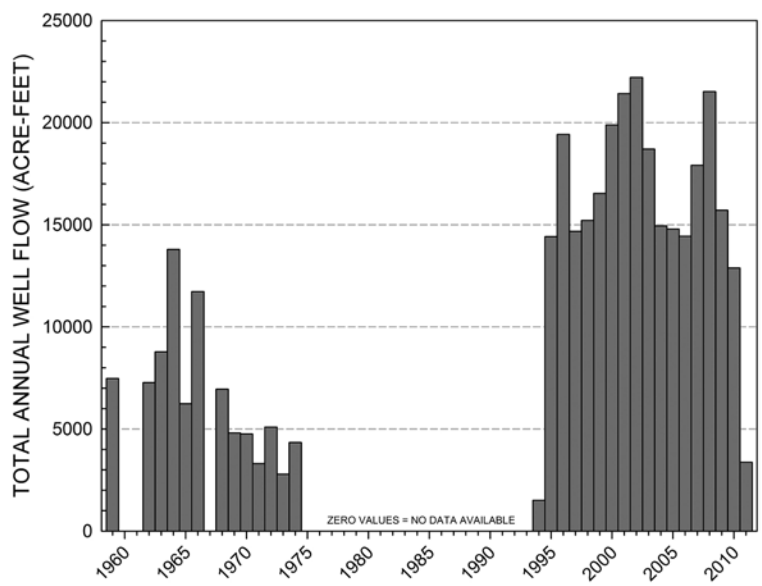

Figure 32. Total annual groundwater pumping at Camas National Wildlife Refuge. Unpublished data compiled from refuge office files.

During the 1920s, sagebrush was the most abundant native plant, "growing luxuriantly almost everywhere except in swampy tracts where it has been killed by the rise of the water table" (Stearns et al. 1939:7). Deteriorating range condition on CNWR was noted during 1951 when drought conditions resulted in very little plant growth and poor range condition. Sagebrush steppe communities are dominated by seeded species, non-native annuals and/or shrubs that have outcompeted native bunchgrasses. Some areas of the refuge that supported sagebrush and diverse native bunchgrasses now are monocultures of crested wheatgrass, which was the most dominant floristic of sandy uplands during 2009 (Germino et al. 2010).

Introduced cheatgrass (*Bromus tectorum*) was widely established in sagebrush habitats throughout the Intermountain West by the 1930s, further displacing native herbaceous plants in sagebrush habitats.

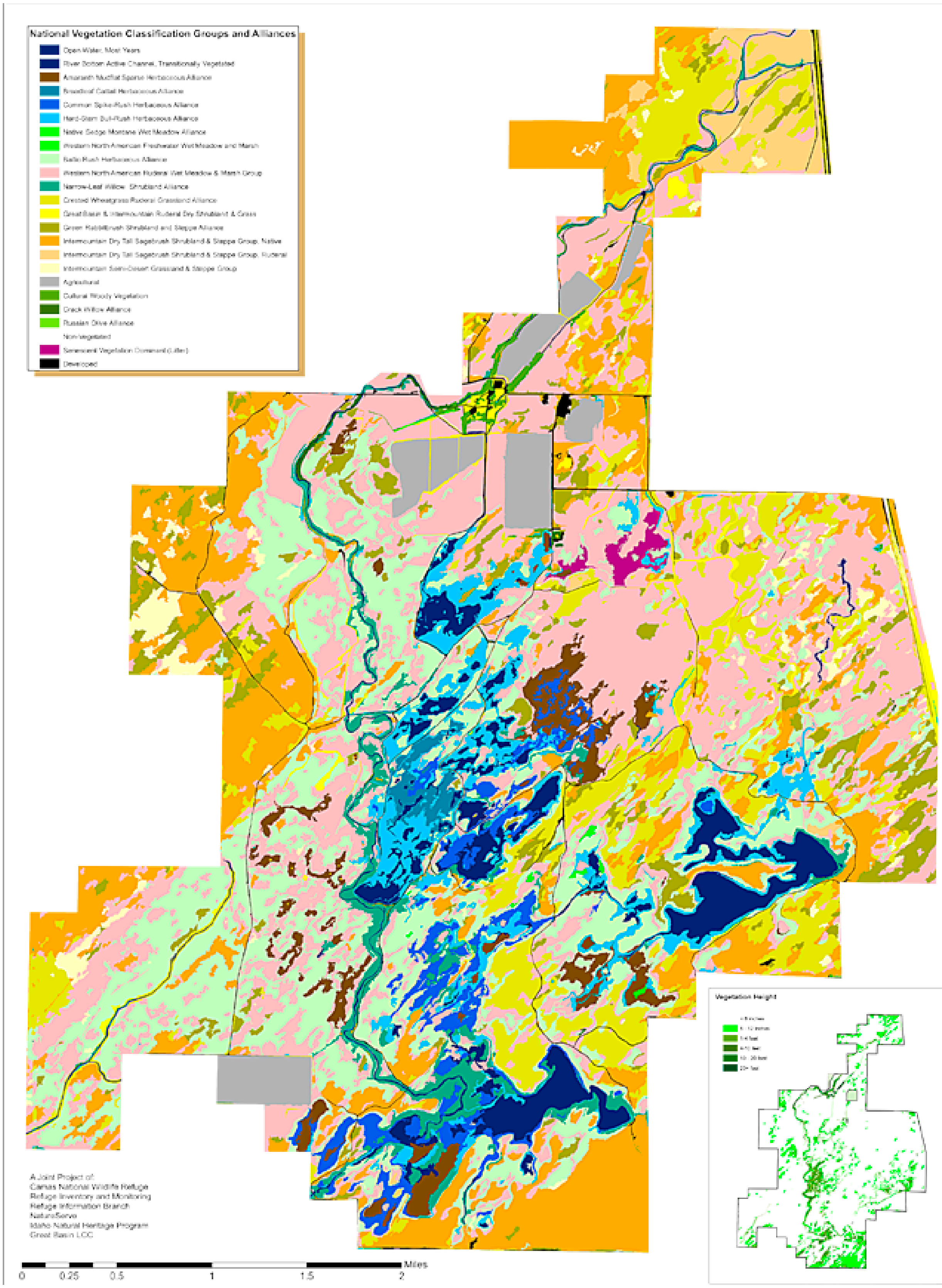

Figure 33. Distribution of vegetation communities at Camas National Wildlife Refuge during 2011. From NatureServe (2012).

Cheatgrass appeared in southern Idaho around 1900 and was the dominant herbaceous species on 6 million acres of sagebrush steppe and/or arid grasslands and comprised up to 25% cover on an additional 10 to 15 million acres by the late-1940s, particularly the vast expanse of the Snake River Plain (Stewart and Hull 1949). Cheatgrass has been identified as one of the most important threats to native sagebrush habitats (Suring et al. 2005) and occurs with other non-native annuals as the second most dominant floristic of sandy uplands at CNWR (Germino et al. 2010). When invaded by annual grasses, sagebrush communities cross an ecological threshold requiring major investments to restore these areas back to a native sagebrush/bunchgrass state (West 1999a,b).

Canada thistle (*Cirsium arvense*) became one of the most problematic invasive species in meadow habitats at CNWR during the 1950s and this management challenge continues today. Other invasive species on the refuge include prickly lettuce (*Lactuca serriola*), kochia (*Kochia scoparia*), Russian knapweed (*Actroptilon repens*), sowthistle (*Sonchus arvensis*), and bindweed (*Convolvulus arvensis*). Average non-native plant cover ranged from about 20 to > 40% in all habitat types during 2009 (Germino et al. 2010).

Historical fire suppression, rangeland deterioration, increased invasive grasses, and/or increased woody shrubs, has resulted in an increased risk of large, high intensity fires throughout the western United States. Greater than 80% of the 48 wildfires in the ESRP from 1980 to 1995 occurred where annual grasses represented >50% herbaceous cover (Knapp 1998). Compared to historical low intensity fires, large, severe fires result in limited heterogeneity following burns (e.g., lack unburned islands) and increase potential for erosion and spread of invasive plants. Removal of sagebrush (e.g., following fire or direct removal) increases the abundance of non-native herbaceous species, in part, as a result of increased soil moisture following removal of sagebrush (Prevéy et al. 2010).

The reduced extent and altered species composition of sagebrush steppe habitats have affected populations of sagebrush obligate species. Population estimates of wintering sage grouse ranged from 2,000 to 3,000 birds during the early-1940s, but have declined since then, with estimates ranging 0 to 1,000 wintering birds (USFWS refuge annual narratives). Population trends of other sagebrush obligate species at CNWR are not known. Following declines in the late-1800s, game herds in eastern Idaho increased from the 1920s to 1960s, but then declined through the 1980s (Wessink 1986).

Similar to sagebrush steppe uplands, wetland habitats have also significantly changed since European settlement. Total palustrine herbaceous emergent wetland habitat acres are similar to historical condition; however, composition and distribution of habitats vary from the Presettlement period. Comparison of currently mapped wetland habitats (NatureServe 2012) with historical habitats (this study) are difficult because nearly half (47%) of the current palustrine emergent herbaceous wetlands are classified as a non-native ruderal wet meadow and marsh group (Fig. 33) (NatureServe 2012), which includes multiple flooding regimes (e.g., wet meadow, seasonal, and semi-permanently flooded habitat types). However, descriptions of wetland habitats from USFWS refuge annual narratives provide insights into how wetland habitats have changed.

Cattails increased during the 1950s as a result of water management in pond units that had longer and more static hydroperiods. By 1961, 60% of the total pond area consisted of "stagnant stands of cattail" (USFWS refuge annual narratives). Although some areas of open water still produced good submerged aquatic vegetation, emergent vegetation continued to be dominated by dense cattails and bulrush through the 1990s. For example, the western portion of Center Pond and Big, Redhead, and Toomey Ponds are dominated by cattail, bulrush, and open water/submerged aquatic vegetation. Although some of these areas have an interspersion of robust emergent vegetation with open water, most stands of emergent vegetation are decadent with dense growth and accumulated organic matter. Bulrush (485 acres) is currently more abundant than cattails (52 acres). The area of open water has increased from an estimated 152 acres historically (this study) to 373 acres during the 1980s (Fig. 34) to 439 acres during 2011 (NatureServe 2012).

During 1951, refuge staff noted the "deterioration in character and quality of plant growth as a result of the diversion ditch being deepened" at Buck Springs (USFWS refuge annual narratives). Construction and deepening of ditches at CNWR altered subsurface flow by increasing lateral drainage of shallow groundwater, especially in areas where ditches dissect subsurface soil with coarser texture than surface soils. Some portion of surface water diverted from Camas Creek at the north end of the refuge is also lost to infiltration or evaporation as it flows down long canals that cross sandy soil

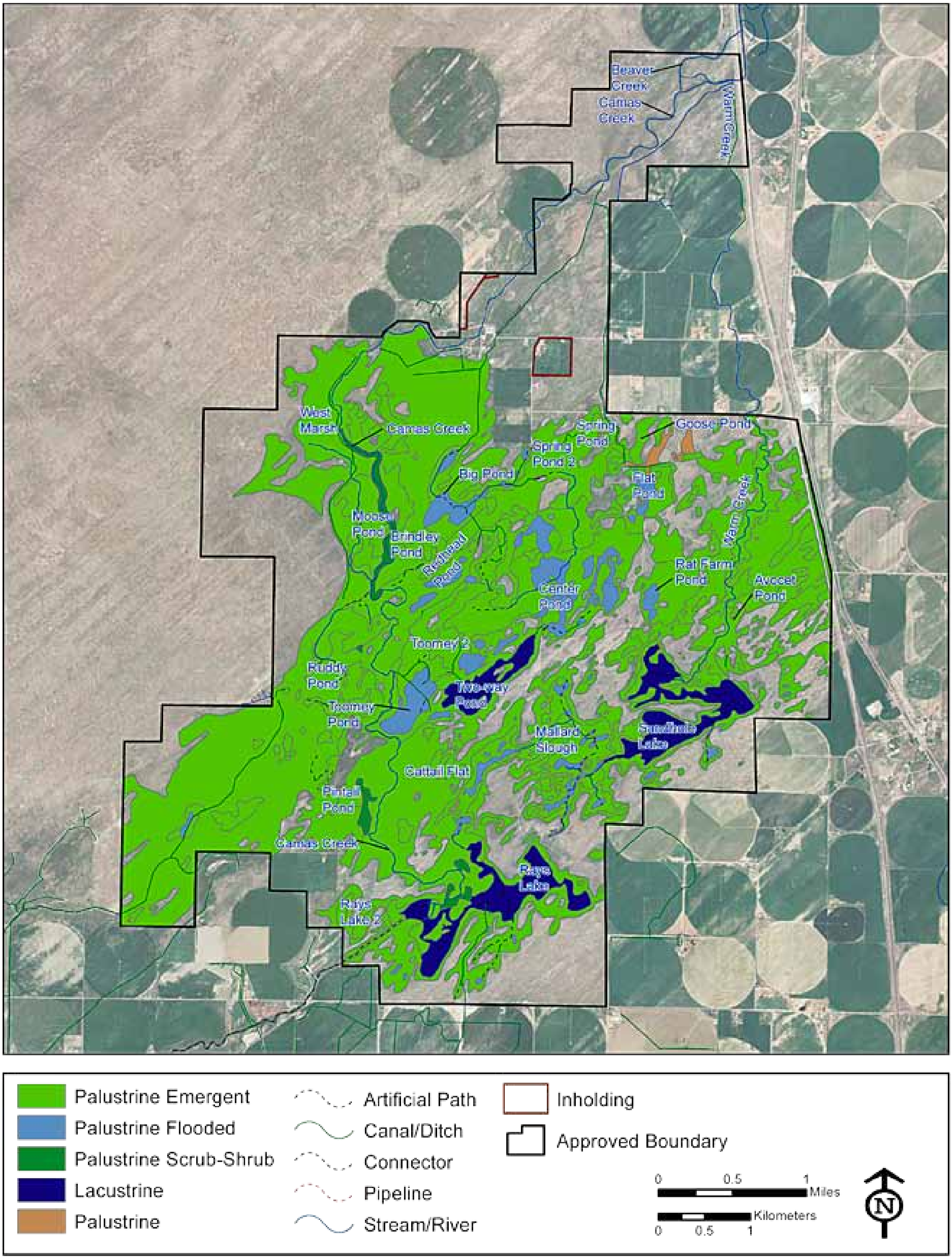

Figure 34. Wetland types at Camas National Wildlife Refuge. Data from USFWS National Wetland Inventory (http://www.fws.gov/wetlands/) and USGS 1:24,000 National Hydrography Dataset (http://nhd.usgs.gov/). Compiled by USFWS (2012).

types. Upstream land uses adjacent to Camas Creek and associated erosion have increased sedimentation and suspended sediments that abrade and suffocate periphyton, decrease primary production, and disrupt respiration and modify behavior of aquatic invertebrates (Waters 1995).

Woody vegetation communities have encroached on historically herbaceous riparian zones and displace native herbaceous wetland habitats, both seasonal and semi-permanently flooded habitats. Many non-native and native species were planted by early settlers and refuge staff (see previous section). Willows have expanded through natural germination, likely as a result of altered stream functions, including dredging and increased height of stream banks. Coyote willow dominates the riparian habitat adjacent to Camas Creek, (Fig. 33) (NatureServe 2012), occupying 277 acres of historically herbaceous wetland habitats. Coyote willow can tolerate wetter conditions than most other willows (Nellessen 2002) and commonly occurs along irrigation canals in southeastern Idaho. Crack willow (*S. fragilis*) was introduced into Idaho during the 1970s and has invaded native willow habitats at Rays Lake. Dredging of canals may also lower groundwater levels in the shallow alluvial aquifer increasing drainage of poorly and very poorly drained soils further contributing to increased growth of woody vegetation.

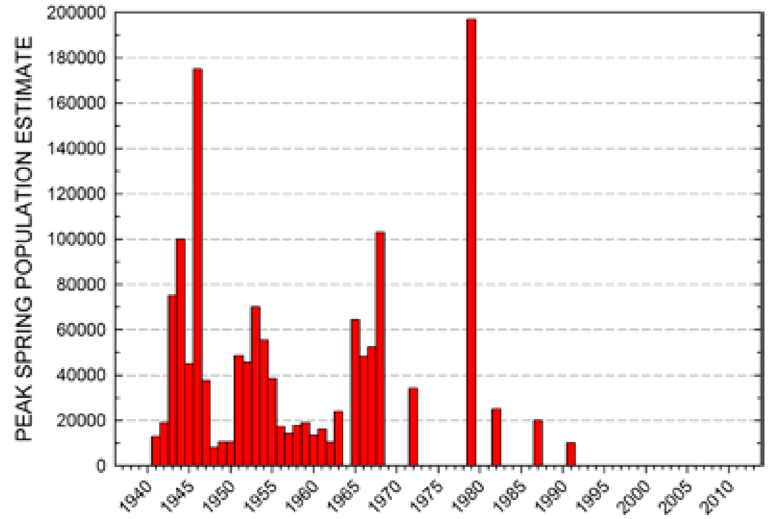

Figure 35. Peak estimates of waterfowl at Camas National Wildlife Refuge during spring 1941-1995. Zero values indicate no data are available. Unpublished data compiled from refuge office files.

Waterfowl population estimates are available from USFWS refuge annual narratives and were compiled by USFWS staff (USFWS unpublished data). Peak spring migration ranges from 15 March to 20 April and peak fall migration ranges from 15 September to 21 December. Estimates in peak population numbers are similar between spring and fall, ranging from about 10,000 to 200,000 birds (Fig. 35). Waterfowl production estimates range from less than 1,000 to 18,000. Although methods of estimating waterfowl populations at CNWR since it was established varied over time, most of the highest estimates occurred during the early-1940s (USFWS unpublished data). Trumpeter swans at CNWR have produced above replacement levels since 1980, however, no cygnets have successfully fledged from 2006 through 2012 (Henry and Shea 2011, USFWS unpublished data).

Muskrat population estimates following the 1930s and 1940s are sporadically reported, but populations continued to fluctuate during wet/dry cycles. The distribution of muskrats throughout the refuge shifted depending on available habitats, and their benefit to controlling cattail generally outweighed the holes dug into dikes and berms (USFWS refuge annual narratives). Following the population peak of 10,000 muskrats during the 1940s wet period, the peak population during the 1960s wet period was only 5,000 (USFWS refuge annual narratives) suggesting that the number of muskrats CWNR could support during wet years may have decreased. However, comparison with muskrat populations prior to substantial anthropogenic modifications is not possible.

The planted cottonwood shelterbelt, including a mix of native and non-native trees and shrubs, supports a large and diverse number of migrating landbirds with likely higher populations compared to Presettlement conditions. More than 75 species of landbirds were observed during 2005-2007 surveys. Some of the most frequently observed species included hermit thrushes (*Catharus guttatus*) and Wilson's warblers (*Cardellina pusilla*) (Carlisle et al. 2008).

PREDICTED IMPACTS OF FUTURE CLIMATE CHANGE

Climatic trends in the western U.S. during the 20th century may be in part related to the interdecadal climate variability associated with the

Pacific decadal oscillation (PDO), but also appear to be influenced by the monotonic warming, which is largely unrelated to the PDO (Knowles et al. 2006, Mote 2006). Reduced snowpack and earlier stream flow appear to be greater or vary significantly from natural variability and are attributed to climate changes caused by anthropogenic greenhouse gases, ozone, aerosols, and land use (Pierce et al. 2008, Hidalgo et al. 2009).

Temperatures in the western United States are projected to increase by at least 1.8 °F to 3.6 °F by 2050 (Baron et al. 2004) and up to 8°F by 2095 (Hamlet and Lettenmaier 1999) resulting in extensive changes to water resources throughout the region. The most significant impact of this warming will be a reduced winter snowpack and the associated reduction in natural water storage (Barnett et al. 2004). Reduced natural water storage, combined with higher summer temperatures and decreases in humidity will result in higher water temperatures, increased fire danger, and reduced ability to meet irrigation needs (Barnett et al. 2004). Earlier snowmelt and stream flow will affect the timing of surface water inputs into CNWR and aquifer recharge from tributary underflows.

Modeling of climate change impacts on groundwater resources worldwide is limited and results are highly variable due to the complex nature of aquifers (Green et al. 2011). It is not known if overall groundwater recharge will increase, decrease, or stay the same at any scale in the western US (Dettinger and Earman 2007 as cited in Green et al. 2011). However, changes in timing and amount of precipitation in the Centennial Mountains will undoubtedly affect timing and amount of tributary underflow recharge to the aquifer. If the increased probability of extreme high precipitation events observed in the 20th century continues to occur, then recharge to aquifers may decrease because of increased/accelerated surface water runoff that occurs during and immediately after high intensity precipitation events. Increased intensity of precipitation may also cause increased erosion from upland areas/mountain slopes and fans into valley marsh areas.

Predictions of future climate change are likely to have some effect on sagebrush and other upland communities in the ESRP. Increases in temperatures may extend the fire season and cause an increase in larger more severe fires in arid upland habitats in the Intermountain West. Increasing temperatures may also cause shifts in species distribution. Increased CO_2 may increase the growth of plants with C3 photosynthesis pathways, including both native and non-native species (Chambers 2008). This is a potential concern at CNWR and other areas in the ESRP because the production of cheatgrass may increase under elevated CO_2 levels, subsequently increasing fuel loads and creating a positive feedback loop of increased fire frequency and extent (Smith et al. 1987, Ziska et al. 2005, Link et al. 2006).

Adonia Henry

OPTIONS FOR ECOSYSTEM RESTORATION AND MANAGEMENT

SYNTHESIS OF HGM INFORMATION

Information obtained and synthesized were sufficient to conduct an HGM-based evaluation of historical and current conditions at CWNR and the surrounding region. A dominant landform characteristic of CNWR is the shallow Mud Lake alluvial aquifer formed from lacustrine deposits of pluvial Lake Terreton and its juxtaposition with basalt lava flows and alluvial processes on Camas Creek.

CNWR historically contained wetlands fed by ground and surface water inputs that were influenced by highly variable seasonal, annual, and long-term patterns in snowfall, spring runoff, and local precipitation events. Although the temporal variation in range of wetland and upland habitat conditions at CNWR may never be known because of extensive man-made modifications dating back to the late-1800s, synthesis of historical accounts, long-term hydrological data, and paleoclimate analyses enabled reconstruction of historical vegetation communities. The driving ecological process of alternating flooding and drying with more permanent water located near Sandhole and Mud lakes created and maintained important wetland systems at CNWR in the extensive sagebrush steppe ecosystem of the semi-arid ESRP.

Historically, annual surface water inputs into CNWR were temporally dynamic. Groundwater discharge and the interaction of surface and groundwater inputs were also important factors that sustained wetland habitats at CNWR. Based on historical descriptions of the impacts of ditches and recent observations by refuge staff, the movement of water as sheetflow and subsurface flow through spatially and laterally diverse soils was an important factor in sustaining wetland habitats, particularly during drier periods. In addition, overbank flooding of Camas Creek maintained important ecological processes in its floodplain, including nutrient cycling, sediment transport, and flood-attenuation. Wet/dry cycles were also important drivers in sagebrush steppe communities where native bunchgrasses can significantly increase during wet years.

The physical integrity of the shallow Mud Lake alluvial aquifer and the Camas Creek floodplain has been highly altered by infrastructure developments to transport water for irrigation and to create more permanent and stable wetland conditions at CNWR. These infrastructure developments (e.g., berms, ditches, dredging Camas Creek) and water management at CNWR have dramatically changed the historical seasonal, annual, and long-term dynamics of native plant communities in wetlands. In turn, these changes in hydrology, a primary ecological driver of the CNWR ecosystem, in conjunction with structural elements (e.g., topography), have impacted resources used by many animal species. Other agricultural developments, primarily irrigation practices on the Egin Bench and groundwater withdrawals, have altered the hydrologic condition of the regional basalt ESRP aquifer, which has also impacted native habitats at CNWR. Further, conversion of native sagebrush steppe and grazing pastures to croplands in much of the watershed adjacent to CNWR has degraded the quality of surface water inputs and altered natural infiltration processes that recharge the regional ESRP and shallow alluvial Mud Lake aquifers.

Major challenges for future management of CNWR will be: 1) managing for natural wetland processes that provide abundant resources for wetland-dependent species while mimicking the large range of natural variability that historically characterized habitats at the refuge; 2) controlling invasive species; 3) collaborating with the surrounding landowners on flood control, water conservation, and sustainable land use issues; and 4) adapting to predicted impacts of future climate change. Consequently, future management issues that affect timing, distribution, and movement of water on the refuge must consider how, and if, management actions are actually contributing to desired objectives of 1) restoring native communities and their ecological processes and 2) increasing the resilience of the CNWR and Mud Lake ecosystem to adapt to a changing climate. Additionally, future management of the refuge must seek to define the role of the refuge lands in a larger landscape-scale conservation and restoration strategy for the Beaver-Camas watershed, as well as state, regional, and flyway efforts for restoring native habitats that support abundant animal populations during important life-history stages.

RECOMMENDATIONS FOR ECOSYSTEM RESTORATION AND MANAGEMENT

This study identifies a range of restoration and management options that will protect and sustain natural ecosystem processes, functions, and, in turn, resource values at CNWR. The HGM evaluation process is system-based first, with the goal of sustaining the ecosystem. These system-based recommendations are based on the assumption that if the integrity of the system is maintained and/or restored, that key resources for species of concern will be provided. This approach is consistent with recent recommendations to manage the NWR system to improve the ecological integrity and biodiversity of landscapes in which they sit (Fischman and Adamcik 2011).

The HGM process seeks to identify options to restore and maintain system-based processes, communities, and resources that ultimately will help support local and regional populations of native species, both plant and animal, and other ecosystem functions, values, and services.

The refuge provides key resources to meet annual life history requirements for a diverse assemblage of native bird, mammal, and reptile species that should be addressed within the context of a holistic system and regional landscape objectives. CNWR also is an important area that can provide opportunities for wildlife-dependent recreation and education. These public uses are important management issues; however, this study does not address where, or if, competing resources and public use can be accommodated on the refuge. This report provides ecological information to support resource management priorities identified for refuges in the National Wildlife Refuge System Administration Act of 1966, as amended (16 USC 668dd-668ee). Specifically, the National Wildlife Refuge Improvement Act of 1997 (Public Law 105-57) seeks to ensure that the biological integrity, diversity, and environmental health of the system are maintained (USFWS 1999, Meretsky et al. 2006). Step-down policies that articulate the importance of conserving "a diversity of fish, wildlife and plants and their habitats" and conserving unique, rare, or declining ecosystems (601 FW 1) include mandates for assessing a refuge's importance across multiple spatial scales and recognizing that restoration and/or management of historical natural processes is critical to achieve goals (601 FW 3).

Most of the CCPs completed for refuges include restoration of native habitats as one of their primary goals. However, limited information is provided about how restoration will be accomplished considering the existing and often highly modified landscapes in which refuges are located. Historical conditions (those prior to substantial human-related changes to the landscape) are often selected as the benchmark condition (Meretsky et al. 2006), but restoration to these historical conditions may not be well-understood, feasible, or cost-effective, thereby compromising success of restoration actions. USFWS policy (601 FW 3) directs managers to assess not only historical conditions, but also "opportunities and limitations to maintaining and restoring" such conditions. Furthermore, USFWS guidance documents for NWR management "favor management that restores or mimics natural ecosystem processes or functions to achieve refuge purpose(s)" (620 FW 1 and 601 FW 3).

Considering USFWS policies and legal mandates guiding management of refuges, the HGM approach provides a basis for developing recommendations for future management. CNWR was established as a "refuge and breeding ground for migratory birds and other wildlife." Consequently, future management of CNWR must attempt to sustain and restore historical ecosystem processes and resources to provide habitat for migratory birds and other native species. Management of native habitats and ecological restoration are primary goals in the draft CCP for CNWR (USFWS 2014). Recommendations of this HGM assessment, based on the examination of historical ecosystem conditions, suggest that wetland and riparian habitats can be restored to more functional systems.

All native habitats within CNWR should be protected, restored, and/or managed to 1) provide resources used and required by native animal species, and 2) increase the resiliency of the ecosystem to future environmental stressors (e.g., climate change). Recommendations resulting from this HGM evaluation address three management adaptation approaches that have been identified as important to increase the resilience of ecosystems to respond to projected future climate changes. These management adaptations include the following: reducing anthropogenic stresses; protecting key ecosystem features; and restoring ecosystems that have been lost (Baron et al. 2008). Collaboration with other landowners in the Beaver-Camas subbasin is essential to protect surface and subsurface processes that impact CNWR and to address predicted impacts of climate change. Regional- and landscape-scale collaboration with multiple partners and disciplines is highlighted in the USFWS climate change strategy (USFWS 2010) and in flood control protection that emphasizes implementing sustainable flood management measures (e.g., Tyagi et al. 2006, Birkland et al. 2003).

Given constraints of surrounding land uses and current flood control efforts, mandates for restoring and managing ecosystem integrity, opportunities for within refuge and watershed scale conservation, and the HGM findings, we recommend that the future management of CNWR should consider the following goals:

1. Protect and restore the physical integrity and hydrologic processes of the shallow Mud Lake alluvial aquifer beneath CNWR and surrounding lands.

2. Restore natural topography and surface water flows, and where necessary manage flows to mimic natural hydrological conditions and maintain water rights.

3. Restore and/or manage for the diversity, composition, distribution, and regenerating mechanisms of diverse, self-sustaining native wetland and upland vegetation communities in relation to geomorphic landscape position.

4. Provide key resources that mimic natural patterns of resource availability and abundance for native species during appropriate life history stages.

The following recommendations are suggested to achieve the above ecosystem restoration and management goals for CNWR.

1. Protect and restore the physical integrity and hydrologic processes of the shallow Mud Lake alluvial aquifer beneath CNWR and surrounding lands.

Geologic landforms including pluvial Lake Terreton, alluvial fans, wind-blown sediments, and volcanic basalt flows created a complex stratigraphy beneath CNWR. Lacustrine deposits from various stages of Lake Terreton created a shallow alluvial aquifer with a perched water table in the Mud Lake region. Silty clay, clay, and clay loam soils slowed percolation of surface water flows from Camas Creek and its tributaries, creating a perched water table that supported a range of wetland habitats on relict lakebed soils. Sedimentary interbeds in the alluvial aquifer also created locally confining conditions resulting in groundwater discharge. Although not as well studied as the regional ESRP aquifer, these diverse characteristics of the shallow alluvial aquifer, often described as complex, are the ecological processes driving wetland habitats at CNWR.

Historical observations suggest water development infrastructure, primarily ditches, have negatively affected water levels in the shallow alluvial aquifer and, therefore, may compromise the natural capacity of the shallow alluvial aquifer to hold water. Protecting the alluvial aquifer from further degradation and restoration of the physical integrity and hydrologic processes of the shallow alluvial aquifer are two of the most important steps for improving management of wetland habitats at CNWR. Specific recommendations that protect and restore the shallow alluvial aquifer include:

1.1 Develop a conceptual groundwater model for the shallow alluvial aquifer at CNWR and the Mud Lake area.

- Quantify the interaction of groundwater in the shallow alluvial aquifer with surface water and groundwater in the regional

ESRP aquifer. Detailed modeling has been done for the regional ESRP aquifer, however very limited information is available on the complex shallow alluvial aquifer at CWNR.

- Identify and quantify the impacts of infrastructure development (e.g., ditches, wells, and berms) on shallow groundwater flow patterns, including water levels, direction, and magnitude of flow.
- Develop site-specific water budgets for CNWR and priority management areas within the refuge that include all sources of water gains (inputs) and water losses (outputs). Water budgets are an important component of water use planning for wetlands as they can identify seasonal and geographic patterns of hydrologic processes (Dunne and Leopold 1978, Carter 1996).

1.2 *Re-establish shallow groundwater flow patterns and water-holding capacity of the shallow alluvial aquifer beneath CNWR where it has been compromised.*

- Avoid constructing additional ditches or excavating borrow areas that may dissect coarse subsurface soil layers, thereby further accelerating subsurface drainage.
- Evaluate alternative water delivery mechanisms (e.g., pipes instead of ditches) to convey water for wetland management objectives.
- Fill ditches or canals that dissect coarse soil layers (e.g., sand or gravel soil deposits) with silty clay, clay, or clay loam soils to reduce lateral drainage of groundwater in wet meadows and other wetland habitats. Where existing ditches or canals dissect coarse soil layers, the potential to effectively hold surface water has been compromised. A careful evaluation of the material used to fill these ditches must be made if on-site material is the most economically feasible option.
- Evaluate the potential to move points of water diversion from surface water right sources closer to managed wetland areas while ensuring all water rights, especially senior water rights, are maintained. These new points of diversion should help eliminate the need for lengthy delivery canals and ditches and reduce water loss associated with these ditches. For example, the current Main Diversion and Eastside canals cross soil types that are well to excessively-drained and cause some surface water to be lost through direct infiltration in soils. Changing points of diversion may also allow increased instream flow in the natural Camas Creek channel.
- Collaborate with the Independent Water Users Group to develop mutually beneficial solutions that 1) facilitate sustainable water delivery from Buck Springs across refuge lands and 2) restore subsurface groundwater flows to CNWR. Historical observations associated with cleaning and deepening Independent Ditch suggest that these actions lowered water levels on surrounding refuge lands. This hydrological impact likely continues because the ditch crosses soil types with as low as 5% clay in subsurface layers compared to up to 60% clay in soil layers closer to the soil surface.

1.3 *Work collaboratively with ESRP agencies, groups, and landowners to re-establish shallow groundwater flow patterns in the shallow alluvial aquifer surrounding CNWR and throughout the Mud Lake basin.*

- Collaborate with NRCS to encourage sustainable water delivery and agricultural practices on private farm and ranch lands.
- Collaborate with NRCS and evaluate the potential for flowage and/or conservation easements on relict lakebed soils outside of CNWR that have been drained and/or where water holding capacity has been compromised by ditches.
- Monitor water rights applications and infrastructure development to ensure activities outside of CNWR are not negatively impacting the shallow alluvial aquifer and USFWS water rights.
- According to Idaho Water Law, ensure that any senior water rights on Camas Creek held by USFWS are not compromised by lower priority withdrawals.

1.4 Collaborate with other landowners in the Beaver-Camas subbasin to identify watershed areas that negatively affect erosion and sedimentation.

- Collaborate with NRCS to encourage implementation of soil conservation practices on private agricultural lands. For example, conservation practices implemented on cultivated croplands in the Chesapeake Bay watershed reduced edge of field losses of sediment, or eroded soil, by 60% (NRCS 2013a).
- Collaborate with state and federal agencies to reduce soil erosion from public lands within the watershed.

2. Restore natural topography and surface water flows and, where necessary, manage flows to mimic natural hydrological conditions and maintain water rights.

Long-term, annual, and seasonal variation in the hydroperiod (depth, duration, and extent of flooding) of wetland habitats at CNWR resulted from highly variable precipitation, snowmelt runoff, and groundwater interactions in the watershed. Prior to alternations in topography and water flow patterns, surface water at CNWR rose following spring runoff and local precipitation events, most notably during the fall. Water content of the snowpack during the previous winter and weather conditions during the spring and summer largely determined wetland conditions during the growing season and affected water levels in the shallow Mud Lake alluvial and regional ESRP aquifers. Cooler temperatures during September and October, especially during wet years, resulted in some shallowly flooded areas extending into the fall. Areas of groundwater discharge likely contributed to extended flooding regimes during some years. Superimposed on the seasonal and annual patterns were long-term fluctuations in precipitation and flooding that created peaks and lows every 15-20 years, contributing to a relatively long wet-dry cycle of 30-40 years. This variable long-term, annual, and seasonal flow of water meandered through Camas Creek and spread out over complex topography and soils at CNWR and the Mud Lake area.

Many changes have occurred at CNWR and within the Beaver-Camas subbasin resulting from alterations in topography and water movement patterns. Most water and wetland infrastructure development at CNWR expanded on the previous infrastructure that was designed for agricultural purposes. Water diversions for irrigation and flood control outside of the present day CNWR boundary have also impacted the surface water flow in Camas Creek and its tributaries. Grazing by domestic livestock and conversion of land to agricultural production throughout the watershed also has resulted in changes to topography, surface and subsurface flows and sediment transport.

The key to maintaining and restoring the abundance, distribution, and diversity of functional plant and animal communities at CNWR is restoring natural long-term, annual, and seasonal dynamics of flooding and drying. Recent advances in understanding of wetland ecology, especially those types with substantial naturally occurring wet and dry annual dynamics, indicate successful long-term restoration of system integrity and productivity requires restoration and/or management of seasonally and annually dynamic water regimes (including occasional drying), restoration of natural sources and patterns of water flow and movement, and restoration of natural topography, where possible (e.g., Laubhan et al. 2012, Heitmeyer et al. 2013). Maintenance and restoration of natural topography and water regimes/flow patterns is also critical to non-wetland habitats on the refuge. For example, sheetflow and infiltration of surface water runoff from mountain valleys and across alluvial fans are important drivers of sagebrush-steppe and wet meadow communities (West and Young 2000).

Water management at CNWR should seek to mimic these dynamics by restoring topography and natural water flow pathways, implementing careful manipulations of water in respective habitat areas to mimic historical variation in hydroperiods, and installing the appropriate infrastructure to do so. Specific recommendations include the following:

2.1 Restore natural topography and reconnect natural surface flow patterns.

- Restore natural topographic features to agricultural fields that historically were leveled, but are no longer used for crop production. The topographic map surveyed during 1937 (Fig. 7) can be used as a benchmark to reconstruct historical topography.

- Remove artificially high berms along Camas Creek and re-contour instream channel characteristics considering historical survey notes and GLO maps. Advances in applied stream channel morphology and flood pulsing concepts (e.g., Rosgen 1996, Middleton 2002) can inform stream channel and surface flow restoration design.

- Evaluate the potential to use induced meandering techniques to restore incised portions of Camas Creek and its tributaries as a basis for restoring floodplain connectivity (Zeedyk 2009, Zeedyk and Clothier 2012).

- Lower, remove, or modify berms that restrict flow of surface water across CNWR. Hydrological engineering analyses will be needed to design structural modifications such as constructing spillways, breaches, and low-water crossings in levees and roads.

- Relocate berms along natural elevation contours and soil type boundaries to facilitate management of natural hydrologic conditions. Using permeable fill in roads may facilitate restoration of wet meadows (Zeedyk 1996) and other wetland types at CNWR.

- Evaluate the potential to fill ditches as described under recommendation #1.

2.2 *Improve water source and management capabilities.*

- Evaluate the potential to move the point of diversion for the existing Camas Creek water right currently at the Main Diversion Structure downstream so that it is closer to areas of historical semi-permanently flooded wetland habitats. This will restore instream flows while reducing water lost to evaporation and infiltration while transported through the 2.6 mile Main Diversion Canal that crosses sandy upland soils. Any changes to water rights should be done according to Idaho law and ensure senior water rights are maintained.

- Evaluate the potential to split the point of diversion for Camas Creek water rights into multiple points of diversion as occurred historically. This will likely be beneficial to wetland management and restoring surface water flow patterns.

2.3 *Change water management in permanently and semi-permanently flooded wetlands to match natural hydroperiods.*

- Update the existing water management plan for CNWR to incorporate temporal and spatial variability in hydrologic conditions in managed wetland units. This is an important step to restore productive wetland conditions.

- Emulate a natural cycle in managed wetlands by not keeping water level the same (often referred to full pool elevation) every year.

- Vary the hydroperiod (depth, duration, and extent of flooding) in managed wetlands through time. Temporal variability (including drawdowns) should mimic naturally dynamic hydrological conditions.

2.4 *Collaborate with surrounding landowners and water managers to develop ecologically sound integrated flood management measures.*

- Contribute to planning efforts that incorporate environmental and ecosystem considerations for integrated flood management practices (see Tyagi et al. 2006).

- Maximize restoration of surface water flow patterns and overbank flooding within CNWR to increase flood attenuation capabilities.

- Encourage and collaborate on efforts to restore riparian and wetland habitats throughout the Beaver-Camas subbasin that increase flood attenuation capabilities of the watershed.

- Partner with landowners in the Beaver-Camas subbasin and adjacent watersheds to restore natural flood attenuation and sediment reduction conditions.

- Limit flood management measures that increase the velocity or restrict movement of flood water onto and through CNWR.

3. Restore and/or manage for the diversity, composition, distribution, and regen-

erating mechanisms of diverse, self-sustaining native wetland and upland vegetation communities in relation to geomorphic landscape position.

The distribution of native upland and wetland plant species occurs in response to variations in environmental factors and interactions among plants and other organisms. Physiological adaptations of plants enable them to colonize, germinate, grow, and successfully reproduce under favorable abiotic (environmental and physical) conditions. Historical land uses and management actions at CNWR (e.g., stable water levels, domestic livestock grazing, planting of non-native species, agricultural crops, and altered fire regimes) have changed the abiotic conditions, ecological processes, and the biological interactions among species.

The complex geological history, spatial variability of soil types, and large temporal variability of surface water inputs across seasonal, annual, and multi-decadal time frames suggest that environmental conditions created a dynamic mosaic of native habitats at CNWR. However, historical management actions promoted stable water conditions, which resulted in a dominance of one or a few wetland plant species that are adapted to those conditions. Existing semi-permanently flooded habitats at CNWR are indicative of climax communities where stable and consistent water conditions have been managed for a relatively long period. In addition, ditches originally designed for agricultural purposes likely drained some wet meadow habitats and transported water to habitats not naturally flooded. Sagebrush steppe habitats have been impacted by domestic livestock grazing, invasive species, and altered fire regimes. Specific recommendations to restore natural ecological processes that support self-sustaining native vegetation communities include the following:

3.1 *Restore temporally and spatially diverse complexes of native wetland and upland communities with natural water regimes and adequate infrastructure to mimic natural hydrologic conditions.*

- Restore surface water connectivity as described in recommendation #2 to enhance hydrological processes (e.g., sheetflow, nutrient transport) associated with native plant communities.
- Control and/or eradicate non-native invasive vegetation in all habitat types.
- Implement management strategies that mimic natural disturbance regimes to can help sustain native habitats after they are restored.

3.2 *Re-design and/or rehabilitate existing wetland units (not restored to natural conditions) in relation to topographic and geomorphic landscape position to improve wetland management capabilities and enhance habitat quality.*

- Evaluate existing management units to identify modifications that may be needed to enhance management of the abiotic conditions required to produce resources for priority wetland-dependent species.
- Reconfigure wetland unit boundaries that cross multiple soil types to improve effectiveness of water management actions. Low profile berms should be placed along topographic contours and soil type boundaries to maximize management potential.
- Evaluate wetland units with multiple soil types to determine the most appropriate water management strategy.
- Conduct more detailed soil mapping on some mapped soil types that include multiple soil series with very different characteristics (e.g., Grassy Butte-Medano complex) which will contribute to interspersion of habitat types within a management area, to determine site potential and then establish effective management goals and strategies.
- Manage wetland units as complexes of habitat types based on the suitability of specific units to provide diverse resources needed to meet the annual cycle needs of animal species using the refuge during different seasons and over long-term periods of the wet-dry precipitation cycle.

3.3 *Manage wetland areas for natural seasonal, annual, and long-term water dynamics.*

- Change or modify water-control infrastructure in units where possible to allow flexibility for seasonally and inter-annually variable seasonal water regimes.

- Manage wetland areas for different stages of succession to the extent possible to match life history needs of priority wetland-dependent species.
- Manipulate water levels to enhance availability of food and cover resources described below in recommendation #4.
- Conduct water level drawdowns to promote desirable plant species based on plant life history strategies (e.g., germination requirements).

3.4 Collaborate with the Idaho Department of Fish and Game to manage diverse wetland habitats (e.g., Mud Lake, Marty WRP, Market Lake) within the ESRP.

3.5 Restore functional semi-permanently flooded wetland habitats on poorly-drained Fluvaquent soils.

In managed wetland units with a long history of stabilized water levels, managing for several consecutive years of drawdown, combined with other disturbance actions, may be necessary to restore productive, diverse plant communities and wetland processes. These processes include, but are not limited to the following: decomposition of accumulated organic matter; oxidation; nutrient cycling; biogeochemical cycles; seed banks; and mycorrhizae associations (see van der Valk 2006, Keddy 2010). Open water currently covers 65% more area than estimated historically and extended hydroperiods in semi-permanently flooded wetlands has resulted in decadent, unproductive stands of cattail and bulrush.

- Reduce the area of permanently flooded open water habitats and decadent stands of emergent vegetation.
- Manage open water communities for pioneering SAV species (e.g., sago pondweed) with high nutrient values that are adapted to disturbance.
- Manage water level drawdowns to remove decadent stands of robust emergent vegetation.
- Drawdowns should include complete removal of surface water AND soil water within the root zone of plants. Removal of surface water only is not sufficient to stress wetland plant species that are flood tolerant and have large underground biomass capable of storing large quantities of carbohydrates and nutrient reserves (e.g. *Typha*).

3.6 Restore wet meadow habitats in locations that historically supported this vegetation community (Fig. 23).

- Restore natural seasonal sheetwater flows into wet meadow habitats so that short duration shallow inundation is created by removing obstructions to water flow.
- Provide temporally variable annual water management if natural inundation patterns in wet meadow areas cannot be restored for short durations in late spring, and manage water flow across meadow areas in natural sheetflow patterns.
- Prepare a vegetation management plan for meadow areas that can emulate natural vegetation species composition and seasonal structure.
- Remove and recycle plant biomass and bound nutrients, provide natural regeneration substrates, and support high (but annually dynamic) primary and secondary productivity on a regular basis.
- Limit the area of exposed, disturbed soil during restoration and management activities to prevent establishment or expansion of invasive species.
- Control existing non-native, invasive species in wet meadow areas using an integrated pest management approach.

3.7 Restore and manage instream flows to protect fish and wildlife habitat, improve water quality, and sustain herbaceous riparian communities in Beaver and Camas creeks.

- Evaluate instream and riparian habitats at CNWR from the watershed scale because the structure and processes of lotic systems are determined by their connection with adjacent habitats (Briggs 1996).
- Restore natural channel morphology and dynamic flood pulsing within CNWR as described in Recommendation #2.
- Coordinate with other landowners to restore natural channel characteristics upstream and

downstream of CNWR to re-establish sediment and runoff processes.

- Collaborate with NRCS, USFS, and private landowners to reduce sedimentation and erosion upstream of CNWR.
- Encourage development of sustainable livestock management plans in upstream locations that are grazed by livestock and implement soil conservation practices (e.g., stream buffers) in cultivated areas (see also recommendation 1.4).
- Evaluate the feasibility of utilizing natural rehabilitation processes (e.g. Briggs 1996) and/or intensive restoration actions (e.g., Jensen and Platts 1990).
- Lower artificially high berms along Camas Creek to reconnect and allow creek overbank flooding to flow into and across their floodplains.
- Remove accumulated sediment resulting from anthropogenic modifications in the watershed that has altered topography or destroyed native vegetation.
- Mimic natural instream flow dynamics to sustain important, temporally variable hydrologic processes and to create conditions favorable for germination of herbaceous species. Opportunities for protecting instream flows in Idaho are summarized by Brandes (1985).
- Remove woody vegetation (native and non-native species) that has encroached on herbaceous riparian communities after instream flows and associated hydrologic processes are restored and/or managed for.
- Select species adapted to micro-site conditions (e.g., soil type, flooding depth and frequency; Briggs 1996) if planting is used to augment establishment of native vegetation.

3.8 *Protect and restore native sagebrush steppe and salt desert shrub communities on appropriate soil types (see Fig. 23, Table 2).*

- Protect existing native sagebrush steppe and salt desert shrub habitats from conversion to non-native types (e.g., invasive annual grasses) and habitat fragmentation.
- Minimize physical disturbance to eolian and mixed alluvium deposits on lava plains that support remnant sagebrush steppe and salt desert shrub communities.
- Identify and prioritize management actions for sagebrush steppe and salt desert shrub habitats based on the results of 2009 rangeland survey (Germino et al. 2010) and 2011 habitat mapping and vegetation inventory (NatureServe 2012). Areas that have not crossed the identified ecological thresholds should be a higher priority for restoration and management.
- Restore natural surface water sheetflow and infiltration patterns (see Recommendations for #2 above) to remnant native habitats and areas identified for restoration.
- Protect and maintain remnant sagebrush steppe communities by mimicking or maintaining self-sustaining natural disturbance patterns.
- Prescribed fire should be carefully evaluated and only used if absolutely necessary. A spatial mosaic of low intensity burns with relatively long (> 50 years) fire return intervals may be beneficial for sagebrush steppe habitat; however, there is a risk of invasion by non-native annual grasses from nearby adjacent sites.
- Develop an integrated pest management plan to control existing non-native vegetation, reduce the potential for further spread of invasive species, and implement rapid response measures when new populations or new species are identified.
- Ensure that upland vegetation management actions do not inadvertently increase erosion and siltation into riparian, wet meadow, or marsh habitats.

3.9 *Manage the current planted cottonwood galleries to restore Camas Creek instream flows.*

Although cottonwoods apparently were not historically present along Camas Creek and other riparian areas in the CNWR region, the current planted cottonwood galleries may provide some important resources for certain landbirds. If these artificial cottonwood habitats are maintained, they should be confined to sizes and locations that minimize consumption of water that is important to restore Camas Creek instream flows and downstream native herbaceous wetland habitats

- Manage artificial cottonwood habitats to minimize consumption of limited water resources.
- Remove planted woody species that are non-native or invasive (i.e., Russian olive, Siberian pea).
- Do not re-establish trees as they die off unless planted trees can be maintained through natural hydrology. For example, future planting should consider soil type (e.g., texture and profiles) and hydrologic processes to ensure maximum survival and growth with minimal management.
- Collaborate with landowners in the ESRP to manage other planted shelterbelts to provide this artificial habitat, thereby further conserving limited water resources at CNWR.

4. Provide key resources that mimic natural patterns of resource availability and abundance for native species during appropriate life history stages.

4.1 Identify resource needs for life-cycle events of priority species to develop targets for habitat management actions.

CNWR cannot expect to provide resources for all life-cycle events or all species, so management should focus on the life cycle events and resource needs of priority species in relationship to available regional and flyway resources. Resources required by migratory birds within the broad life history events currently identified in the draft CPP (breeding, foraging, and over-wintering) vary considerably. Therefore, to efficiently and effectively provide critical resources on CNWR, it is necessary to further describe life-history stages such as spring migration, pre-breeding, egg-laying, incubation, brood-rearing, molting, fall migration, and over-wintering. This should be done for each of the 30 priority species of migratory birds currently identified by CNWR. For example, sago pondweed is a high quality food resource for trumpeter swans, and the availability of midge larvae during egg-laying has been linked to clutch size in some species of diving ducks. Management actions identified in Recommendation #3 that produce these and other important food resources will support productive populations of waterbirds.

It is important to recognize that the timing of life history events may be different for males and females of the same species (e.g., mallard and other waterfowl species' molt periods) when they are present on CNWR.

4.2 Identify the life-cycle event and known resource needs for priority species of mammals, amphibians, reptiles, and invertebrates (see 4.1).

4.3 Manage for availability and dynamics of key resources that coincide with life history strategies of priority species, including plant and invertebrate food sources high in nutrients, appropriate structure and interspersion of vegetative cover, and refuge (e.g., areas of no disturbance) for priority species during appropriate life history stages (see 4.1).

Management of wetland habitats for long-lived k-selected species, such as trumpeter swans, should include some periodic consecutive years of consistent abundant resources (such as annual flooding of emergent-SAV habitats) that can improve the probability of successful breeding. The length and timing of consecutive years of abundant resources within select units will vary by species and must be managed within the context of natural long-term inter-annual dynamics of wetland flooding and drying (see previous recommendations about the need for temporally variable flooding regimes). As such, periods of high resource abundance cannot be maintained every year for long periods at every wetland because managing for stable conditions will eventually result in a long-term decline of habitat conditions and food resources.

- Improve water management across a functional complex of wetland areas as described in Recommendations #2 and #3 to mimic temporal and spatial availability of resources.
- Manage different successional stages of semi-permanently flooded wetlands across multiple wetland units with at least one unit at maximum productivity each year.
- Manage wetland habitats to provide resources for species of concern in Idaho, given the extensive wetland losses in Idaho (estimated 56% loss from 1780s to 1980s;

Dahl 1990) and other areas in the Pacific Flyway (up to 90%), while considering spatial and temporal variability of productive wetland habitats.

- Manage riparian habitats to provide key resources for wetland-dependent species as well as species typically associated with upland habitats (e.g. sage grouse).

- Manage sagebrush steppe habitats to provide structure and cover required for sagebrush dependent species.

4.4 *Control non-native and invasive species that form monocultures of vegetation, tend to have lower resource values, and compete with higher quality native vegetation (see specific recommendations for #3 above).*

4.5 *Provide refuge areas that include multiple habitat types and minimize human disturbance to focal species during key life history stages.*

- Evaluate public use programs to ensure that public uses do not unnecessarily disturb priority species during key life history stages.

- Ensure that management and research actions minimize disturbance to priority species during key life history events as much as possible.

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MONITORING AND SCIENTIFIC INFORMATION NEEDS

Future management of CNWR should include routine monitoring and management-oriented research to determine how ecosystem structure and function are changing, regardless of whether restoration and management options identified in this report are undertaken. Ultimately, the success in restoring and sustaining communities and ecosystem functions/values at CNWR will depend on how well the physical and hydrological integrity of the shallow alluvial Mud Lake aquifer is protected and how key ecological processes and events, especially naturally variable seasonal and annual flooding and groundwater flows, can be restored or mimicked by management actions. Recommendations in this report address these critical issues and propose restoration of fundamental ecological processes that drive ecosystem function. Nonetheless, uncertainty exists about the ability to make some system changes considering constraints associated with existing water rights and land uses in the Beaver-Camas watershed. Also, effective techniques for controlling introduced plant species are not entirely known and information on life-history requirements of some native wetland plant species is lacking.

Future management actions at CNWR should be done in an adaptive management context where: 1) predictions about resource responses are articulated through objectives (e.g., reduced density and abundance of cattails, increased availability of high quality food resources) relative to specific management actions (e.g., temporally variable drawdowns) and then 2) follow-up monitoring is conducted to evaluate ecosystem responses of plant and animal communities to management actions.

Many recommendations in this report will increase the resiliency of CNWR by allowing it to better adapt to future climate change. Long-term monitoring of the key ecological processes can inform future management challenges related to climate change. Monitoring and adaptive management implemented to meet ecosystem goals at CNWR are consistent with the USFWS's Strategic Habitat Conservation (SHC) and climate change strategies (National Ecological Assessment Team 2006, 2008, USFWS 2010).

The availability of historical hydrologic data for CNWR (e.g., nearby 100-year climate station, early accounts of water infrastructure development) greatly enhanced the ability of this HGM evaluation to identify potential management options for the refuge. Further, past research and hydrologic studies on the regional ESRP aquifer have been essential in advancing the understanding of the CNWR ecosystem. However, other important data and scientific information needed to more precisely understand HGM relationships and management options are not available. The most important missing scientific information needs include the following: 1) hydrologic data for the shallow alluvial Mud Lake aquifer that can be used to model groundwater levels, direction, and magnitude of flow; 2) detailed contemporary soils data mapped to soil type, including soil profiles; and 3) historical photographs that identify pre-refuge development habitat conditions. If these data, maps, and photographs become available, the HGM relationships, maps, and recommendations provided in this report likely can be refined. Especially critical scientific information and monitoring needs for CNWR are identified below.

KEY BASELINE ECOSYSTEM DATA

If the following baseline abiotic and biotic data are obtained, they can be used to advance multiple scientific information gaps identified in the recommendations. Certain important site-specific data that are currently lacking and needed to implement effective adaptive management at CNWR include the following:

- Detailed soils mapping and descriptions (including soil profiles) to assess where lateral subsurface drainage may be occurring (see recommendations under #1 and #2). These data will be necessary to: 1) improve water delivery infrastructure; and 2) guide rehabilitation of existing managed wetlands or identify areas where restoration of native wetland habitats can occur.
- Detailed hydrologic data for the shallow alluvial Mud Lake aquifer that can be used to model spatially and temporally variable groundwater levels, direction, magnitude of flow, and interaction with surface water (see recommendation 1.1).
- Comprehensive inventory and mapping of submerged aquatic vegetation, which is currently identified as open water on the 2011 habitat map, and its relationship to wetland hydrology (see recommendations 3.5 and 4.3).
- Comprehensive surveys of seasonal movements and habitat use of priority bird species at CNWR in relation to local and regional habitat conditions (see recommendations under #3 and #4).

RESTORING OR MANAGING FOR NATURAL WATER REGIMES AND FLOW PATTERNS

Several physical and management changes are recommended to help restore or enhance natural topography, water flow, and flooding dynamics at CNWR (see recommendations under #2 and #3). Most changes involve restoring at least some natural water flow in Camas Creek and wetland units for more seasonally- and annually-dynamic flooding and drying regimes. The following monitoring will be important to evaluate the effects of these changes if implemented:

- Continued annual monitoring of water use for refuge areas including source and delivery mechanisms or infrastructure.
- Documentation of how water moves across CNWR at various precipitation events and stream stage-discharge conditions. This should include long-term evaluation of surface and groundwater interactions and flow across and through alluvial fans and basalt flows in the Beaver-Camas subbasin and into CNWR.
- Annual monitoring of the depth, duration, and extent of flooding and drying at different sites (e.g., stratified by elevation, soil type, etc), and relationships with non-refuge water and land uses. This will require a series of staff gauges in managed, restored, and remnant wetland habitats, inflows and outflows, groundwater wells, and piezometers tied to elevation.
- Monitoring soil moisture in relation to controlled and uncontrolled inputs as well as environmental variability associated with wind, clouds, residual vegetation, soil texture, and organic matter is relevant for assessing optimal germination conditions for native species and management of productive habitats.
- Monitoring of water quality, including salinity, conductivity, suspended sediments, and nutrients, throughout the refuge.

LONG-TERM CHANGES IN VEGETATION AND ANIMAL COMMUNITIES

Recent monitoring of plant and animal communities and populations on CNWR has been confined mostly to a few target species such as trumpeter swans and landbirds. Although historical data are most readily available for waterfowl, analyses that assess linkages among populations, habitat use, and availability of resources are lacking. Annual waterfowl population estimates are not available since USFWS refuge annual narratives were stopped during 1995; data since then are sporadic. Data on other animal species are also limited. Monitoring certain species may be especially important because they are indicators of community status, habitat condition, or species of concern, introduced or invasive, and either increasing or decreasing over longer terms at unusual rates. In addition to determining current distribution and dynamics of species, long-term surveys and monitoring programs are needed to understand changes over time and in relation to management activities. Important surveys for plants and animals include:

- Distribution and composition of major plant communities and priority species over time, including expansion or contraction rates of invasive plant species and cover of tall emergent vegetation.
- Associations between native and invasive wetland plant species, physical conditions (e.g., soil type, hydrology), and management activities (e.g., soil disturbance).
- Survival, growth, and regeneration rates of native and introduced species in sagebrush steppe and salt desert shrub habitats following disturbance or management actions.
- Abundance, chronology of life history events, habitat use and availability, juvenile and adult survival, and recruitment of priority bird species.
- Occurrence and abundance of other priority animal species.
- Occurrence, abundance, and availability of aquatic invertebrates as a food resource for waterbirds.

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ACKNOWLEDGEMENTS

This HGM evaluation was funded through contract #F10PD80295 between USFWS and Blue Heron Conservation Design and Printing LLC. Major funding for the project was provided by the USFWS Region 1 Inventory and Monitoring Initiative (I&M). Kevin Kilbride, I&M coordinator, initiated the project and was the primary administrative support from the USFWS office in Vancouver, Washington. He also reviewed the report and provided insights on USFWS policy related to restoration and management. Brian Wehausen, manager at CNWR, and John Braastad, Deputy Project Leader for Southeast Idaho NWR (SEID) Complex, assisted with field visits, project meetings, data acquisition, and reviewed the report. Pam Johnson, biologist at CNWR, provided historical data and reviewed the report. Mike Fisher, supervisory biologist for SEID Complex (retired), provided biological data. Jenny Barnett, I&M zone biologist assisted with project meetings and the current vegetation map. Sheila Strachan, hydrologist with the USFWS Water Resources Branch, provided assistance with hydrological data and reviewed the report. Tom Miewald, landscape ecologist and data coordinator for USFWS Science Applications and Refuges, scanned historical maps and provided assistance with GIS, LiDAR, and the current vegetation map. Erin Stockenberg, I&M data manager, assisted with GIS data. Karen Kyle of Blue Heron Conservation Design and Printing LLC administered the contract for the project and designed, formatted, and published the final report.

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Appendix A. Vegetation species known and expected to occur in vegetation community types on Camas National Wildlife Refuge (CNWR). For Other Habitat, GF=Planted Gallery Forest. For status, N=native, PL=native, but planted at CNWR and not likely present under natural conditions, I=introduced/invasive, and I*=noxious weed designated by the State of Idaho (http://www.agri.state.id.us/) and/or invasive weed identified by CNWR (unpublished data). For growth type, A=annual, B=biennial, and P=perennial. Species list compiled from Hitchcock and Cronquist (1973), Germino et al. (2010), CNWR plant list (USFWS 2014),and Jefferson and surrounding counties plant list (Consortium of Pacific Northwest Herbaria 2014). Species data compiled from various botanical sources, including Bolen (1964), Cronquist et al. (1972), Youngblood et al. (1985), Padgett et al. (1989), Hurd et al. (1997), Hurd et al. (1998), Weber and Hanks (2006), USDA PLANTS Database (http://plants.usda.gov), USDA USFS Fire Effects Information System (http://www.fs.fed.us/database/feis/plants), Native Plant Information Network (http://www.wildflower.org), Flora of North America (http://www.efloras.org/), University of Washington Burke Museum (http://biology.burke.washington.edu/herbarium/imagecollection.php), Calflora Database (http://www.calflora.org), and the Colorado Plant Database (http://jeffco.us/coopext/intro.jsp). Nomenclature follows Integrated Taxonomic information Systen (http://www.itis.gov, accessed May 2013 and March 2014).

		Habitats									
Common Name	*Scientific Name*	Riverine/ Herbaceous Riparian	Robust Emer-gent & SAV	Short Emer-gent	Wet Meadow	Alkali/ Saline Wet Meadow	Salt Desert Shrub/ Grass-land	Sage-brush Steppe	Other	Status	Growth Type
FERN AND FERN ALLIES											
Equisetaceae											
Common Horsetail	*Equisetum arvense*	x		x	x					N	P
Smooth Scouring-rush	*Equisetum laevigatum*	x		x	x					N	P
Marsileaceae											
Hairy Waterclover	*Marsilea vestita*	x	x	x	x	x				N	P
GYMNOSPERMS											
Cupressaceae											
Utah Juniper	*Juniperus osteosperma*							x		N	P
Rocky Mountain Juniper	*Juniperus scopulorum*							x		N	P
Pinaceae											
Scots Pine	*Pinus sylvestris*								GF	PL	P
MONOCOTS											
Alismataceae											
American Water Plantain	*Alisma plantago-aquatica*	x		x						I	P
Northern Water Plantain	*Alisma triviale*	x		x	x					N	P
Northern Arrowhead	*Sagittaria cuneata*	x	x	x						N	P
Amaryllidaceae											
Taper-tip Onion	*Allium acuminatum*							x		N	P
Prairie Onion	*Allium textile*							x		N	P
Araceae											
Common Duckweed	*Lemna minor*	x	x	x						N	P
Star Duckweed	*Lemna trisulca*	x	x	x						N	P
Greater Duckweed	*Spirodela polyrrhiza*	x	x	x						N	P
Asparagaceae											
False Solomon's Seal	*Maianthemum stellatum*	x						x		N	P
Cyperaceae											
Cosmopolitan Bulrush	*Bolboschoenus maritimus*	x	x			x				N	P
Water Sedge	*Carex aquatilis*	x		x						N	P
Slough Sedge	*Carex atherodes*	x	x	x						N	P
Slenderbeak Sedge	*Carex athrostachya*				x					N	P
Golden Sedge	*Carex aurea*	x		x	x					N	P
Douglas' Sedge	*Carex douglasii*	x			x			x		N	P
Needleleaf Sedge	*Carex duriuscula*							x		N	P
Threadleaf Sedge	*Carex filifolia*						x	x		N	P
Hood's Sedge	*Carex hoodii*				x					N	P
Woolly-fruit Sedge	*Carex lasiocarpa*	x	x	x						N	P
Tufted Sedge	*Carex lenticularis*				x					N	P
Smallwing Sedge	*Carex microptera*	x			x					N	P
Nebraska Sedge	*Carex nebrascensis*				x			x		N	P
Woolly Sedge	*Carex pellita*	x	x	x	x					N	P
Clustered Field Sedge	*Carex praegracilis*	x		x	x	x				N	P
Knotsheath Sedge	*Carex retrorsa*	x	x	x	x					N	P
Ross' Sedge	*Carex rossii*							x		N	P

Continued next page

Appendix A, continued.

Common Name	*Scientific Name*	Habitats: Riverine/ Herbaceous Riparian	Robust Emer-gent & SAV	Short Emer-gent	Wet Meadow	Alkali/ Saline Wet Meadow	Salt Desert Shrub/ Grass-land	Sage-brush Steppe	Other	Status	Growth Type
Beaked Sedge	*Carex rostrata*	x			x					N	P
Analogue Sedge	*Carex simulata*	x		x	x	x				N	P
Northwest Territory Sedge	*Carex utriculata*	x		x						N	P
Valley Sedge	*Carex vallicola*							x		N	P
Needle Spikerush	*Eleocharis acicularis*	x		x	x					N	A,P
Dwarf Spikerush	*Eleocharis coloradoensis*	x			x	x				N	P
Pale Spikerush	*Eleocharis macrostachya*	x			x	x				N	P
Common Spikerush	*Eleocharis palustris*	x	x	x		x				N	P
Fewflower Spikerush	*Eleocharis quinqueflora*	x		x	x					N	P
Beaked Spikerush	*Eleocharis rostellata*				x	x				N	P
Panicled Bulrush	*Scirpus microcarpus*	x		x	x					N	P
Hardstem Bulrush	*Schoenoplectus acutus* var. *acutus*		x							N	P
Olney Bulrush	*Schoenoplectus americanus*		x			x				N	P
Common Three-square	*Schoenoplectus pungens*		x	x	x	x				N	P
Hydrocharitaceae											
Slender Naiad	*Najas flexilis*	x	x	x						N	A
Iridaceae											
Rocky Mountain Iris	*Iris missouriensis*	x			x					N	P
Idaho Blue-eyed Grass	*Sisyrinchium idahoense*	x			x					N	P
Juncaceae (Rushes)											
Baltic Rush	*Juncus balticus*	x			x	x				N	P
Colorado Rush	*Juncus confusus*				x					N	P
Swordleaf Rush	*Juncus ensifolius*	x		x	x					N	P
Longstyle Rush	*Juncus longistylis*				x					N	P
Rocky Mountain Rush	*Juncus saximontanus*				x					N	P
Torrey's Rush	*Juncus torreyi*	x			x	x				N	P
Field Woodrush	*Luzula campestris*	x		x	x					I	P
Millet Woodrush	*Luzula parviflora*	x		x	x					N	P
Juncaginaceae											
Seaside Arrowgrass	*Triglochin maritima*	x			x	x				N	P
Marsh Arrowgrass	*Triglochin palustris*	x			x	x				N	P
Lilaceae											
Bruneau Mariposa Lily	*Calochortus bruneaunis*							x		N	P
Sagebrush Mariposa Lily	*Calochortus macrocarpus*							x		N	P
Sego Lily	*Calochortus nuttallii*							x		N	P
Spotted Fritillary	*Fritillaria atropurpurea*							x		N	P
Yellow Bells	*Fritillaria pudica*							x		N	P
Melanthiaceae											
Foothill Deathcamas	*Toxicoscordion paniculatum*							x		N	P
Meadow Deathcamas	*Toxicoscordion venenosum*				x			x		N	P
Orchidaceae											
White bog orchid	*Platanthera dilatata*	x			x					N	P
Ute ladies' tresses	*Spiranthes diluvialis*	x			x					N	P
Poaceae											
Indian Ricegrass	*Achnatherum hymenoides*						x	x		N	P
Letterman Needlegrass	*Achnatherum lettermanii*						x	x		N	P
Columbia Needlegrass	*Achnatherum nelsonii*							x		N	P
Thurber's Needlegrass	*Achnatherum thurberianum*							x		N	P
Webber's Needlegrass	*Achnatherum webberi*							x		N	P
Crested Wheatgrass	*Agropyron cristatum*						x	x		I	P
Redtop	*Agrostis gigantea*	x			x	x				I	P

Continued next page

Appendix A, continued.

Common Name	*Scientific Name*	Habitats: Riverine/ Herbaceous Riparian	Robust Emer- gent & SAV	Short Emer- gent	Wet Meadow	Alkali/ Saline Wet Meadow	Salt Desert Shrub/ Grass- land	Sage- brush Steppe	Other	Status	Growth Type
Rough Bentgrass	*Agrostis scabra*	x			x					N	P
Creeping Bentgrass	*Agrostis stolonifera*	x			x	x	x	x		N	P
Shortawn Foxtail	*Alopecurus aequalis*	x			x					N	P
Meadow Foxtail	*Alopecurus pratensis*				x					I	P
American Sloughgrass	*Beckmannia syzigachne*	x	x	x						N	A
Mountain Brome	*Bromus carinatus*						x	x		N	P
Smooth Brome	*Bromus inermis*	x			x		x	x		N,I	P
Cheatgrass	*Bromus tectorum*						x	x		I	A
Bluejoint Reedgrass	*Calamagrostis canadensis*	x			x			x		N	P
Northern Reedgrass	*Calamagrostis stricta*	x		x	x					N	P
Tufted Hairgrass	*Deschampsia cespitosa*				x	x	x			N	P
Inland Saltgrass	*Distichlis spicata*					x	x			N	P
Barnyardgrass	*Echinochloa crus-galli*			x	x					I	A
Bearded Wheatgrass	*Elymus caninus*				x					I	P
Bottlebrush squirreltail	*Elymus elymoides*						x	x		N	P
Blue Wildrye	*Elymus glaucus*	x			x			x		N	P
Thickspike Wheatgrass	*Elymus lanceolatus* ssp. *lanceolatus*						x	x		N	P
Streamside Wheatgrass	*Elymus lanceolatus* ssp. *riparius*	x			x					N	P
Quackgrass	*Elymus repens*				x		x	x		I	P
Slender Wheatgrass	*Elymus trachycaulus*				x	x	x	x		N	P
Idaho fescue	*Festuca idahoensis*							x		N	P
Tall Mannagrass	*Glyceria elata*	x		x	x					N	P
American Mannagrass	*Glyceria grandis*	x		x	x					N	P
Northwestern Mannagrass	*Glyceria X occidentalis*	x	x	x	x					N	P
Fowl Mannagrass	*Glyceria striata*			x	x					N	P
Needle and Thread	*Hesperostipa comata*						x	x		N	P
Meadow Barley	*Hordeum brachyantherum*	x			x	x	x			N	P
Foxtail Barley	*Hordeum jubatum*				x	x	x			N	P
Barley	*Hordeum vulgare*				cultivated areas					I	A
Prairie Junegrass	*Koeleria macrantha*						x	x		N	P
Spike Fescue	*Leucopoa kingii*							x		N	P
Basin Wildrye	*Leymus cinereus*				x			x		N	P
Yellow Wildrye	*Leymus flavescens*							x		N	P
Creeping Wildrye	*Leymus triticoides*	x			x		x			N	P
Alkali Muhly	*Muhlenbergia asperifolia*	x			x		x	x		N	P
Pullup Muhly	*Muhlenbergia filiformis*	x			x					N	A
Spiked Muhly	*Muhlenbergia glomerata*	x	x	x	x					N	P
Mat Muhly	*Muhlenbergia richardsonis*				x		x	x		N	P
Witchgrass	*Panicum capillare*				disturbed areas					N	A
Western Wheatgrass	*Pascopyrum smithii*						x	x		N	P
Reed Canarygrass	*Phalaris arundinacea*	x	x	x	x	x				N,I	P
Timothy	*Phleum pratense*				x			x		I	P
Fowl Bluegrass	*Poa palustris*	x			x			x		N	P
Kentucky Bluegrass	*Poa pratensis*	x			x		x	x		I	P
Alkali Bluegrass	*Poa secunda* ssp. *juncifolia*						x	x		N	P
Sandberg Bluegrass	*Poa secunda* ssp. *secunda*							x		N	P
Rough Bluegrass	*Poa trivialis*	x			x	x	x	x		I	P
Rabbitfoot Grass	*Polypogon monspeliensis*				x					I	A
Bluebunch Wheatgrass	*Pseudoroegneria spicata*						x	x		N	P
Alkali Cordgrass	*Spartina gracilis*	x			x	x				N	P
Alkali Sacaton	*Sporobolus airoides*						x	x		N	P
Sand Dropseed	*Sporobolus cryptandrus*	x					x	x		N	P
Tall Wheatgrass	*Thinopyrum elongatum*					x	x			I	P

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Appendix A, continued.

Common Name	*Scientific Name*	Habitats: Riverine/ Herbaceous Riparian	Robust Emer-gent & SAV	Short Emer-gent	Wet Meadow	Alkali/ Saline Wet Meadow	Salt Desert Shrub/ Grass-land	Sage-brush Steppe	Other	Status	Growth Type
Oatgrass	*Trisetum* sp.	x			x					N	P
Winter Wheat	*Triticum* sp.				cultivated areas					I	A
Sixweeks Fescue	*Vulpia octoflora*	x					x	x		N	A
Potamogetonaceae											
Waterthread Pondweed	*Potamogeton diversifolius*	x	x							N	P
Ribbon-leaf Pondweed	*Potamogeton epihydrus*	x	x							N	P
Leafy Pondweed	*Potamogeton foliosus*	x	x	x						N	P
Variableleaf Pondweed	*Potamogeton gramineus*	x	x							N	P
Floatingleaf Pondweed	*Potamogeton natans*		x							N	P
Longleaf Pondweed	*Potamogeton nodosus*	x	x							N	P
Small Pondweed	*Potamogeton pusillus*	x	x							N	P
Richardson's Pondweed	*Potamogeton richardsonii*	x	x							N	P
Fern Pondweed	*Potamogeton robbinsii*	x	x							N	P
Fineleaf Pondweed	*Stuckenia filiformis*	x	x							N	P
Sago Pondweed	*Stuckenia pectinata*	x	x	x						N	P
Sheathing Pondweed	*Stuckenia vaginata*		x							N	P
Horned Pondweed	*Zannichellia palustris*	x	x							N	P
Ruppiaceae											
Widgeongrass	*Ruppia maritima*	x	x	x		x				N	P
Typhaceae											
Narrowleaf Burreed	*Sparganium angustifolium*	x	x	x						N	P
Broad-fruited Burreed	*Sparganium eurycarpum*	x	x	x		x				N	P
Broadleaf Cattail	*Typha latifolia*		x	x		x				N	P
DICOTS - FORBS, SHRUBS, & TREES											
Amaranthaceae											
Mat Amaranth	*Amaranthus blitoides*				disturbed areas					I	A
California Amaranth	*Amaranthus californicus*	x			x					N	A
Powell's Pigweed	*Amaranthus powellii*	x			x					N	A
Fourwing Saltbush	*Atriplex canescens*						x	x		N	P
Gardner's Saltbush	*Atriplex gardneri*						x	x		N	P
Lambsquarters	*Chenopodium album*				disturbed sites					I	A
Dark Goosefoot	*Chenopodium atrovirens*							x		N	A
Blight Goosefoot	*Chenopodium capitatum*	x			x			x		N	A
Freemont's Goosefoot	*Chenopodium fremontii*	x						x		N	A
Slimleaf Goosefoot	*Chenopodium leptophyllum*							x		N	A
Spiny Hopsage	*Grayia spinosa*						x	x		N	P
Saltlover/Common Halogeton	*Halogeton glomeratus*						x	x		I	A
Burningbush	*Kochia scoparia*				disturbed sites					I	P
Winterfat	*Krascheninnikovia lanata*						x	x		N	P
Poverty Weed	*Monolepis nuttalliana*	x				x	x			N	A
Russian Thistle	*Salsola kali*						x	x		I	A
Pursh Seepweed	*Suaeda calceoliformis*					x				N	A,P
Bush Seepweed	*Suaeda nigra*					x	x			N	P
Western Seepweed	*Suaeda occidentalis*					x	x			N	A,P
Anacardiaceae											
Fragrant Sumac	*Rhus aromatica*						x	x		N	P
Apiaceae											
Sharptooth Angelica	*Angelica arguta*	x			x					N	P
Western Water Hemlock	*Cicuta douglasii*	x		x	x					N	P
Plains Spring-parsley	*Cymopterus glomeratus*							x		N	P
Utah Spring-parsley	*Cymopterus purpurascens*							x		N	P
Fern Leaf Buiscuitroot	*Lomatium dissectum*							x		N	P

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Appendix A, continued.

Common Name	*Scientific Name*	Habitats								Status	Growth Type
		Riverine/ Herbaceous Riparian	Robust Emer- gent & SAV	Short Emer- gent	Wet Meadow	Alkali/ Saline Wet Meadow	Salt Desert Shrub/ Grass- land	Sage- brush Steppe	Other		
Carrot Leaf Buiscuitroot	*Lomatium foeniculaceum*							x		N	P
Great Basin Desert Parsley	*Lomatium simplex*							x		N	P
Gardner's Yampah	*Perideridia gairdneri*	x			x					N	P
Turpentine Wavewing	*Pteryxia terebinthina*							x		N	P
Apocynaceae											
Common Dogbane	*Apocynum cannabinum*							x		N	P
Showy Milkweed	*Asclepias speciosa*						x	x		N	P
Asteraceae											
Common Yarrow	*Achillea millefolium*				x		x	x		N,I	P
Pale Agoseris	*Agoseris glauca*				x			x		N	P
Annual Bursage	*Ambrosia acanthicarpa*							x		N	A
Rosy Pussytoes	*Antennaria rosea*							x		N	P
Umber Pussytoes	*Antennaria umbrinella*							x		N	P
Common Sagewort	*Artemisia absinthium*				disturbed areas			x		I	P
Biennial Wormwood	*Artemisia biennis*	x						x		N,I	A,B
Silver Sage	*Artemisia cana*	x			x		x	x		N	P
Dragon Sagewort	*Artemisia dracunculus*							x		N	P
White Sagebrush	*Artemisia ludoviciana*	x			x		x	x		N	P
Basin Big Sagebrush	*Artemisia tridentata* ssp. *tridentata*							x		N	P
Wyoming Big Sagebrush	*Artemisia tridentata* ssp. *wyomingensis*							x		N	P
Threetip Sagebrush	*Artemisia tripartita*							x		N	P
Arrowhead Balsamroot	*Balsamorhiza sagittata*	x					x	x		N	P
Nodding Beggartick	*Bidens cernua*	x		x	x					N	A
Musk Thistle	*Carduus nutans*	x			x			x		I*	A,B
Diffuse Knapweed	*Centaurea diffusa*							x		I*	A,P
Douglas' Dustymaiden	*Chaenactis douglasii*						x	x		N	B,P
Skeletonweed	*Chondrilla juncea*							x		I*	P
Green Rabbitbrush	*Chrysothamnus viscidiflorus*						x	x		N	P
Canada Thistle	*Cirsium arvense*	x			x			x		I*	P
Davis' Thistle	*Cirsium inamoenum*							x		N	P
Bull Thistle	*Cirsium vulgare*	x			x		x	x		I	B
Longleaf Hawksbeard	*Crepis acuminata*							x		N	P
Giant Sumpweed	*Cyclachaena xanthifolia*	x			disturbed areas					N	A
Hoary Tansyaster	*Dieteria canescens*	x			x		x	x		N	A,B,P
Rubber Rabbitbrush	*Ericameria nauseosa*							x		N	P
Cutleaf Daisy	*Erigeron compositus*	x						x		N	P
Longleaf Fleabane	*Erigeron corymbosus*							x		N	P
Spreading Fleabane	*Erigeron divergens*	x					x	x		N	B
Threadleaf Fleabane	*Erigeron filifolius*						x	x		N	P
Streamside Fleabane	*Erigeron glabellus*	x			x					N	B,P
Shaggy Fleabane	*Erigeron pumilus*							x		N	P
Common Woolly Sunflower	*Eriophyllum lanatum*							x		N	P
Hairy Gumweed	*Grindelia hirsutula*	x			x	x				N	P
Curlycup Gumweed	*Grindelia squarrosa*						x	x		N	A,B,P
Broom Snakeweed	*Gutierrezia sarothrae*						x	x		N	P
Common Sneezeweed	*Helenium autumnale*	x			x					N	P
Oneflower Helianthella	*Helianthella uniflora*							x		N	P
Common Sunflower	*Helianthus annuus*	x			disturbed areas					N	A
Nuttall's Sunflower	*Helianthus nuttallii*	x			x					N	P
Showy Goldeneye	*Heliomeris multiflora*				disturbed areas					N	P
White Hawkweed	*Hieracium albiflorum*	x								N	P
Scouler's Hawkweed	*Hieracium scouleri*							x		N	P
Slender Hawkweed	*Hieracium triste*	x								N	P
Cooper's Rubberweed	*Hymenoxys cooperi*				disturbed areas			x		N	B,P

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Appendix A, continued.

Common Name	*Scientific Name*	Habitats: Riverine/ Herbaceous Riparian	Robust Emer- gent & SAV	Short Emer- gent	Wet Meadow	Alkali/ Saline Wet Meadow	Salt Desert Shrub/ Grass- land	Sage- brush Steppe	Other	Status	Growth Type
Povertyweed	*Iva axillaris*				x	x	x	x		N	P
Prickly Lettuce	*Lactuca serriola*	x			disturbed areas					I	A,B
Oxeye Daisy	*Leucanthemum vulgare*				disturbed areas					I*	P
Rush-pink	*Lygodesmia grandiflora*							x		N	P
Goldenweed	*Machaerantheraspp.*							x		N	A,B,P
Cluster Tarweed	*Madia glomerata*	x			disturbed areas			x		N	A
Pineapple Weed	*Matricaria discoidea*				disturbed areas					N	A
Nodding Silverpuffs	*Microseris nutans*							x		N	P
Blue Lettuce	*Mulgedium oblongifolium*	x			x					N	B,P
Scotch Thistle	*Onopordum acanthium*	x					x	x		I*	B
Buek's Groundsel	*Packera subnuda*				x					N	P
Bud Sagebrush	*Picrothamnus desertorum*						x	x		N	P
Spiny Skeletonweed	*Pleiacanthus spinosus*							x		N	P
Russian Knapweed	*Rhaponticum repens*	x			x		x	x		I*	P
Western Coneflower	*Rudbeckia occidentalis*				x					N	P
Water Ragwort	*Senecio hydrophilus*	x			x		x			N	B,P
Lambstongue Ragwort	*Senecio integerrimus*							x		N	B,P
Butterweed Groundsel	*Senecio serra*	x			x					N	P
Common Goldenrod	*Solidago canadensis*	x			x					N	P
Missouri Goldenrod	*Solidago missouriensis*						x	x		N	P
Rocky Mountain Goldenrod	*Solidago multiradiata*							x		N	P
Marsh Sowthistle	*Sonchus arvensis*	x			x	x	x	x		I*	P
Stemless Goldenweed	*Stenotus acaulis*							x		N	P
Small Wirelettuce	*Stephanomeria exigua*							x		N	A,B,P
Western Aster	*Symphyotrichum ascendens*							x		N	P
Easton's Aster	*Symphyotrichum eatonii*	x								N	P
Smooth Blue Aster	*Symphyotrichum laeve*							x		N	P
White Panicle Aster	*Symphyotrichum lanceolatum*	x			x					N	P
White Prairie Aster	*Symphyotrichum falcatum*							x		N	P
Short-rayed Alkali Aster	*Symphyotrichum frondosum*	x					x	x		N	A
Leafybract Aster	*Symphyotrichum foliaceum*				x					N	P
Douglas Aster	*Symphyotrichum subspicatum*	x		x	x					N	P
Common Tansy	*Tanacetum vulgare*				disturbed areas					I	P
Dandelion	*Taraxacum officinale*	x			x		x	x		I	P
Spineless Horsebrush	*Tetradymia canescens*						x	x		N	P
Showy Townsend Aster	*Townsendia florifer*							x		N	A,B,P
Yellow Salsify	*Tragopogon dubius*	x			x		x	x		I	A,B
Mule's Ears	*Wyethia amplexicaulis*					x		x		N	P
Common Cocklebur	*Xanthium strumarium*	x			x	x	x	x		N	A
Boraginaceae											
Tarweed Fiddleneck	*Amsinckia lycopsoides*							x		N	A
Quill Cryptantha	*Cryptantha affinis*							x		N	A
Buttecandle	*Cryptantha celosioides*							x		N	B,P
Cusion Cryptantha	*Cryptantha circumscissa*							x		N	A
Bristly Cryptantha	*Cryptantha interrupta*							x		N	B
Snake River Cryptantha	*Cryptantha spiculifera*							x		N	P
Watson's Cryptantha	*Cryptantha watsonii*							x		N	A
Manyflower Stickseed	*Hackelia floribunda*	x			x			x		N	B,P
Blue Stickseed	*Hackelia micrantha*							x		N	P
Common Stickseed	*Hackelia patens*							x		N	P
Flatspine Stickseed	*Lappula occidentalis*						x	x		N	A,B
Western Stoneseed	*Lithospermum ruderale*							x		N	P

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Appendix A, continued.

Common Name	*Scientific Name*	Habitats: Riverine/ Herbaceous Riparian	Robust Emer-gent & SAV	Short Emer-gent	Wet Meadow	Alkali/ Saline Wet Meadow	Salt Desert Shrub/ Grass-land	Sage-brush Steppe	Other	Status	Growth Type
Oblongleaf Bluebells	*Mertensia oblongifolia*							x		N	A,P
Leafy Nama	*Nama densa*							x		N	A
Sticky Phacelia	*Phacelia glandulifera*							x		N	A
Silverleaf Scorpion-weed	*Phacelia hastata*							x		N	P
Variableleaf Scorpionweed	*Phacelia heterophylla*							x		N	B,P
Sleeping Popcornflower	*Plagiobothrys hispidulus*	x			x					N	A
Alkali Popcornflower	*Plagiobothrys leptocladus*					x	x			N	A
Nuttall's Crinklemat	*Tiquilia nuttallii*						x	x		N	A
Brassicaceae											
Pale Madwort	*Alyssum alyssoides*						x	x		I	A,B
Wild Horseradish	*Armoracia rusticana*				disturbed areas					I	P
Wintercress	*Barbarea orthoceras*	x			x					N	B,P
Sagebrush Rockcress	*Boechera cobrensis*							x		N	P
Hairystem Rockcress	*Boechera pauciflora*							x		N	B,P
Dropseed Rockcress	*Boechera pendulocarpa*							x		N	B,P
Reflexed Rockcress	*Boechera retrofracta*							x		N	B,P
Sicklepod Rockcress	*Boechera sparsiflora*							x		N	B,P
Drummond's Rockcress	*Boechera stricta*							x		N	B,P
Black Mustard	*Brassica nigra*				disturbed areas					I	A
Littlepod Falseflax	*Camelina microcarpa*						x	x		I	A,B
Shepherd's-purse	*Capsella bursa-pastoris*				disturbed areas					I	A
Brewer's Bittercress	*Cardamine breweri*	x			x					N	P
Pennsylvania Bittercress	*Cardamine pensylvanica*	x			x					N	A,B,P
Mountain Tansy-mustard	*Descurainia incana*							x		N	A,B,P
Mountain Tansy-mustard	*Descurainia incisa*	x						x		N	B
Pinnate Tansy-mustard	*Descurainia pinnata*	x			x		x	x		N	A,B
Flixweed Tansy-mustard	*Descurainia sophia*				x		x	x		I	A
Western Wallflower	*Erysimum capitatum*							x		N	B,P
Wormseed Wallflower	*Erysimum cheiranthoides*	x			x	x				I	A,B
Common Pepperweed	*Lepidium densiflorum*						x	x		N	A,B
Mountain Pepperweed	*Lepidium montanum*						x	x		N	B,P
Idaho Pepperweed	*Lepidium papilliferum*					x	x	x		N	A,B
Clasping Pepperweed	*Lepidium perfoliatum*						x	x		I	A,B
Manybranched Pepperweed	*Lepidium ramosissimum*				disturbed areas			x		N	P
Virginia Pepperweed	*Lepidium virginicum*	x			disturbed areas			x		N	A,B,P
Watercress	*Nasturtium officinale*	x	x	x						N,I	P
King Bladderpod	*Physaria kingii*						x	x		N	B,P
Middle Butte Bladderpod	*Physaria obdeltata*					x	x	x		N	P
Oregon Twinpod	*Physaria oregona*	x						x		N	P
Bluntleaf Watercress	*Rorippa curvipes*	x			x					N	A,P
Common Watercress	*Rorippa palustris*	x			x					N	A,B,P
Tall Tumble Mustard	*Sisymbrium altissimum*				x		x	x		I	A,B
Flaxleaf Plains Mustard	*Sisymbrium linifolium*						x	x		N	P
Green Prince's Plume	*Stanleya viridiflora*						x	x		N	P
Longbeak Streptanthella	*Streptanthella longirostris*						x	x		N	A,B
Entire-leaved Thelypody	*Thelypodium integrifolium*					x	x			N	B
Manyflower Thelypody	*Thelypodium milleflorum*						x	x		N	B
Field Pennycress	*Thlaspi arvense*				disturbed areas					I	A

Continued next page

Appendix A, continued.

Common Name	*Scientific Name*	Habitats: Riverine/ Herbaceous Riparian	Robust Emer-gent & SAV	Short Emer-gent	Wet Meadow	Alkali/ Saline Wet Meadow	Salt Desert Shrub/ Grass-land	Sage-brush Steppe	Other	Status	Growth Type
Tower Rockcress	*Turritis glabra*	x						x		N	A,B,P
Cactaceae											
Prickly Pear	*Opuntia polyacantha*						x	x		N	P
Campanulaceae											
Bluebell	*Campanula rotundifolia*							x		N	P
Caryophyllaceae											
Ballhead Sandwort	*Eremogone congesta*							x		N	P
King's Sandwort	*Eremogone kingii*							x		N	P
Longstalk Starwort	*Stellaria longipes*	x			x					N	P
Ceratophyllaceae											
Coontail	*Ceratophyllum demersum*	x	x							N	P
Cleomaceae											
Yellow Beeplant	*Peritoma lutea*	x					x	x		N	A
Rocky Mountain Beeplant	*Peritoma serrulata*							x		N	A
Convolvulaceae											
Hedge False Bindweed	*Calystegia sepium*				disturbed areas					I	P
Field Bindweed	*Convolvulus arvensis*	x			x		x	x		I*	P
Buttonbush Dodder	*Cuscuta cephalanthi*	x								N	P
Crassulaceae											
Weakstem Stonecrop	*Sedum debile*							x		N	P
Lanceleaf Stonecrop	*Sedum lanceolatum*							x		N	P
Elaeagnaceae											
Russian Olive	*Elaeagnus angustifolia*								GF	I	P
Silverberry	*Elaeagnus commutata*	x						x		N	P
Silver Buffaloberry	*Shepherdia argentea*	x					x	x		N	P
Euphorbiaceae											
Doveweed	*Croton setiger*				disturbed areas					N	P
Ribseed Sandmat	*Euphorbia glyptosperma*							x		N	A
Fabaceae											
Purple Milkvetch	*Astragalus agrestis*							x		N	P
Silverleaf Milkvetch	*Astragalus argophyllus*					x	x			N	P
Torrey's Milkvetch	*Astragalus calycosus*							x		N	P
Canadian Milkvetch	*Astragalus canadensis*					x	x	x		N	P
Painted Milkvetch	*Astragalus ceramicus*							x		N	P
Hillside Milkvetch	*Astragalus collinus*							x		N	P
Basalt Milkvetch	*Astragalus filipes*							x		N	P
Geyer's Milkvetch	*Astragalus geyeri*							x		N	A,B
Freckled Milkvetch	*Astragalus lentiginosus*						x	x		N	A,B,P
Weedy Milkvetch	*Astragalus miser*				x			x		N	P
Pursh's Milkvetch	*Astragalus purshii*							x		N	P
Siberian Pea	*Caragana arborescens*				x	x	x	x	GF	I	P
Wild Licorice	*Glycyrrhiza lepidota*	x			x					N	P
Utah Sweetvetch	*Hedysarum boreale*							x		N	P
Lanceleaf Scurfpea	*Ladeania lanceolata*							x		N	P
Silvery Lupine	*Lupinus argenteus*	x			x			x		N	P
Dwarf Lupine	*Lupinus caespitosus*							x		N	P
Tailcup Lupine	*Lupinus caudatus*						x	x		N	P
Velvet Lupine	*Lupinus leucophyllus*							x		N	P
Rusty Lupine	*Lupinus pusillus*							x		N	A
Alfalfa	*Medicago sativa*				cultivated areas					I	P
White Sweet-clover	*Melilotus albus*	x			x	x		x		I	A,B,P
Yellow Locoweed	*Oxytropis campestris*							x		N	P
Haresfoot Locoweed	*Oxytropis lagopus*							x		N	P
Lemon Scurfpea	*Psoralidium lanceolatum*							x		N	P
Alkali Swainsonpea	*Sphaerophysa salsula*					x				I	P
Buckbean	*Thermopsis montana*							x		N	P
Red Clover	*Trifolium pratense*				disturbed areas					I	B,P
American Vetch	*Vicia americana*	x			x			x		N	P
Vetch	*Vicia amurensis*	x			x			x		I	P

Continued next page

Appendix A, continued.

Common Name	*Scientific Name*	Habitats								Status	Growth Type
		Riverine/ Herbaceous Riparian	Robust Emer-gent & SAV	Short Emer-gent	Wet Meadow	Alkali/ Saline Wet Meadow	Salt Desert Shrub/ Grass-land	Sage-brush Steppe	Other		
Gentianaceae											
Rocky Mountain Gentian	*Gentiana affinis*				x					N	P
Desert Centaury	*Zeltnera exaltata*				x	x	x			N	A
Geraniaceae											
Ruichardson's Geranium	*Geranium richardsonii*	x			x			x		N	P
Sticky Geranium	*Geranium viscosissimum*							x		N	P
Grossulariaceae											
Wax/Golden Currant	*Ribes aureum*	x			x			x		PL	P
Haloragaceae											
Northern Watermilfoil	*Myriophyllum sibiricum*	x	x							N	P
Andean Watermilfoil	*Myriophyllum quitense*	x	x							N	P
Hypericaceae											
Scouler's St John's Wort	*Hypericum scouleri*	x			x					N	P
Lamiaceae											
Nettleleaf Giant Hyssop	*Agastache urticifolia*							x		N	P
Common Motherwort	*Leonurus cardiaca*				disturbed areas					I	P
Water Horehound	*Lycopus americanus*	x			x					N	P
Field/Wild Mint	*Mentha arvensis*	x			x					N	P
Western False Dragonhead	*Physostegia parviflora*	x			x					N	P
Common Selfheal	*Prunella vulgaris*				x					N,I	P
Marsh Skullcap	*Scutellaria galericulata*	x		x	x					N	P
Marsh Hedgenettle	*Stachys palustris*	x		x	x					I	P
Hairy Hedgenettle	*Stachys pilosa*	x		x	x					N	P
Lentibulariaceae											
Bladderwort	*Utricularia minor*	x	x							N	P
Linaceae											
Blue Flax	*Linum lewisii*							x		N	P
Loasaceae											
Whitestem Blazingstar	*Mentzelia albicaulis*							x		N	A
Smoothstem Blazingstar	*Mentzelia laevicaulis*							x		N	B,P
Malvaceae											
Wild Hollyhock	*Iliamna rivularis*	x			x					N	P
Orange Globemallow	*Sphaeralcea coccinea*						x	x		N	B,P
Munro's Globemallow	*Sphaeralcea munroana*							x		N	P
Nyctaginaceae											
White Sand Verbena	*Abronia mellifera*							x		N	P
Oleaceae											
Ash	*Fraxinus*sp.								GF	PL	P
Onagraceae											
Plains Evening Primrose	*Camissonia contorta*							x		N	A
Fireweed	*Chamerion angustifolium*	x			disturbed areas					N	P
Paiute Suncup	*Chylismia scapoidea*						x	x		N	A
Tall Annual Willowherb	*Epilobium brachycarpum*							x		N	A
Fringed Willowherb	*Epilobium ciliatum*				x			x		N	P
Hornemann's Willowherb	*Epilobium hornemannii*	x								N	P
Alyssum Evening Primrose	*Eremothera boothii* ssp. *alyssoides*						x	x		N	A
Small Evening Primrose	*Eremothera minor*						x	x		N	A
Spreading Groundsmoke	*Gayophytum diffusum*							x		N	A
Pinyon Groundsmoke	*Gayophytum ramosissimum*							x		N	A
Blackfoot River Evening Primrose	*Neoholmgrenia andina*							x		I	A
Tufted Evening Primrose	*Oenothera cespitosa*							x		N	P

Continued next page

Appendix A, continued.

Common Name	*Scientific Name*	Habitats								Status	Growth Type
		Riverine/ Herbaceous Riparian	Robust Emer-gent & SAV	Short Emer-gent	Wet Meadow	Alkali/ Saline Wet Meadow	Salt Desert Shrub/ Grass-land	Sage-brush Steppe	Other		
Yellow Evening Primrose	*Oenothera flava*	x					x	x		N	P
Pale Evening Primrose	*Oenothera pallida*							x		N	B,P
St. Anthony Dunes Evening Primrose	*Oenothera psammophila*							x		N	P
Diffuseflower Evening Primrose	*Taraxia subacaulis*	x			x			x		N	P
Orobanchaceae											
Northwest Paintbrush	*Castilleja angustifolia*						x	x		N	P
Yellow Paintbrush	*Castilleja flava*							x		N	P
Desert Paintbrush	*Castilleja linariifolia*							x		N	P
Scarlet Paintbrush	*Castilleja miniata*	x			x					N	P
Pale Paintbrush	*Castilleja pallescens*							x		N	P
Pilose Paintbrush	*Castilleja pilosa*							x		N	P
Bushy Bird's Beak	*Cordylanthus ramosus*							x		N	A
Broomrape	*Orobanche corymbosa*				parasitic on other plants					N	A
Elephant Head	*Pedicularis groenlandica*	x			x					N	P
Phyrmaceae											
Common Monkeyflower	*Mimulus guttatus*	x			x					N	A,P
Miniature Monkeyflower	*Mimulus suksdorfii*	x			x					N	A
Plantaginaceae											
Autumn Water-starwort	*Callitriche hermaphroditica*	x	x							N	P
Different-leaved Water-starwort	*Callitriche heterophylla*	x	x							N	P
Vernal Water-starwort	*Callitriche palustris*	x	x	x						N	P
Blue-eyed Mary	*Collinsia parviflora*							x		N	A
Common Marestail	*Hippuris vulgaris*		x	x						N	P
Sulphur Beardtongue	*Penstemon attenuatus*							x		N	P
Blue Beardtongue	*Penstemon cyaneus*							x		N	P
Scabland Penstemon	*Penstemon deustus*							x		N	P
Matroot Penstemon	*Penstemon radicosus*							x		N	P
Redwool Plantain	*Plantago eriopoda*				x	x				N	P
Woolly Plantain	*Plantago patagonica*							x		N	A
American Speedwell	*Veronica americana*	x			x					N	P
Chain Speedwell	*Veronica catenata*	x			x					N	B,P
Polemoniaceae											
Sand Gilia	*Aliciella leptomeria*						x	x		N	A
Tiny trumpet	*Collomia linearis*				disturbed areas			x		N	A
Great Basin Woollystar	*Eriastrum sparsiflorum*							x		N	A
Wilcox's Woollystar	*Eriastrum wilcoxii*							x		N	A
Rosy Gilia	*Gilia sinuata*						x	x		N	A
Scarlet Gilia	*Ipomopsis aggregata*							x		N	B,P
Common Ball-head Gilia	*Ipomopsis congesta*						x	x		N	P
Northern Linanthus	*Leptosiphon septentrionalis*				x			x		N	A
Prickly Phlox	*Linanthus pungens*							x		N	P
Slender Phlox	*Microsteris gracilis*							x		N	A
Needleleaf Navarretia	*Navarretia intertexta*	x			x					N	A
Sagebrus Phlox	*Phlox aculeata*							x		N	P
Hood's Phlox	*Phlox hoodii*						x	x		N	P
Longleaf Phlox	*Phlox longifolia*							x		N	P
Flowery Phlox	*Phlox multiflora*							x		N	P
Polygonaceae											
Brittle Spineflower	*Chorizanthe brevicornu*							x		N	A
Watson's Spineflower	*Chorizanthe watsonii*							x		N	A
Mat Buckwheat	*Eriogonum caespitosum*							x		N	P
Nodding Buckwheat	*Eriogonum cernuum*						x	x		N	A
Wyeth's Buckwheat	*Eriogonum heracleoides*							x		N	P
Slender Buckwheat	*Eriogonum microthecum*						x	x		N	P

Continued next page

Appendix A, continued.

Common Name	*Scientific Name*	Habitats: Riverine/ Herbaceous Riparian	Robust Emer-gent & SAV	Short Emer-gent	Wet Meadow	Alkali/ Saline Wet Meadow	Salt Desert Shrub/ Grass-land	Sage-brush Steppe	Other	Status	Growth Type
Cushion Buckwheat	*Eriogonum ovalifolium*							x		N	P
Sulphur Buckwheat	*Eriogonum umbellatum*							x		N	P
Water Smartweed	*Persicaria amphibia*	x		x	x					N	P
Curlytop Knotweed	*Persicaria lapathifolia*	x		x	x					N	A
Spotted Ladysthumb	*Persicaria maculosa*	x		x	x					I	A,P
Prostrate Knotweed	*Polygonum aviculare*	x			x					I	A,P
Douglas' Knotweed	*Polygonum douglasii*				x			x		N	A
Curly Dock	*Rumex crispus*	x			x					I	P
White Willow Dock	*Rumex triangulivalvis*				disturbed areas			x		N	P
Utah Willow Dock	*Rumex utahensis*	x			x					N	P
Veiny Dock	*Rumex venosus*							x		N	P
Portulacaceae											
Purslane	*Portulaca oleracea*				disturbed areas					I	A
Kiss-me-quick	*Portulaca pilosa*							x		N	A,P
Primulaceae											
Filiform Rock Jasmine	*Androsace filiformis*				x					N	A
Sticky Shooting Star	*Dodecatheon pulchellum*	x			x	x	x			N	P
Sea Milkwort	*Glaux maritima*	x			x	x				N	P
Ranunculaceae											
Monkshood	*Aconitum columbianum*	x			x					N	P
Hairy Clematis	*Clematis hirsutissima*				x					N	P
Western Clematis	*Clematis ligusticifolia*	x			x			x		N	P
Anderson's Larkspur	*Delphinium andersonii*							x		N	P
Little Larkspur	*Delphinium bicolor*							x		N	P
Slim Larkspur	*Delphinium depauperatum*				x					N	P
Two-lobe Larkspur	*Delphinium nuttallianum*							x		N	P
Bristly Mousetail	*Myosurus apetalus*	x			x			x		N	A
White Water Crowfoot	*Ranunculus aquatilis*	x	x	x						N	P
Sharpleaf Buttercup	*Ranunculus acriformis*				x					N	P
Pink Buttercup	*Ranunculus andersonii*							x		N	P
Alkali Buttercup	*Ranunculus cymbalaria*	x		x	x	x	x			N	P
Yellow Water Buttercup	*Ranunculus flabellaris*	x		x	x					N	P
Sagebrush Buttercup	*Ranunculus glaberrimus*							x		N	P
Small Yellow Water Buttercup	*Ranunculus gmelinii*	x	x	x	x					N	P
Straightbeak Buttercup	*Ranunculus orthorhynchus*	x			x	x				N	P
Cursed Buttercup	*Ranunculus sceleratus*	x			x	x				N	P
Hooked Buttercup	*Ranunculus uncinatus*	x			x					N	A,P
Fendler's Meadowrue	*Thalictrum fendleri*							x		N	P
Rosaceae											
Western serviceberry	*Amelanchier alnifolia*							x		N	P
Utah Serviceberry	*Amelanchier utahensis*							x		N	P
Desertsweet	*Chamaebatiaria millefolium*							x		N	P
Hawthorne	*Crataegus* sp.								GF	I	P
Shrubby Cinquefoil	*Dasiphora fruticosa*				x			x		N	P
Sticky Cinquefoil	*Drymocallis pseudorupestris*							x		N	P
Largeleaf Avens	*Geum macrophyllum*				x					N	P
Old Man's Whiskers	*Geum triflorum*							x		N	P
Rockspirea	*Holodiscus microphyllus*	x			x			x		N	P
Silverweed Cinquefoil	*Potentilla anserina*	x			x	x				N	P
Biennial Cinquefoil	*Potentilla biennis*				x					N	A,B
Slender Cinquefoil	*Potentilla gracilis*				x	x	x	x		N	P
Chokecherry	*Prunus virginiana*						x	x	GF	PL	P
Antelope Bitterbrush	*Purshia tridentata*						x	x		N	P
Wood's Rose	*Rosa woodsii*							x	GF	N	P
White spirea	*Spiraea betulifolia*	x								N	P
Rubiaceae											

Continued next page

Appendix A, continued.

Common Name	Scientific Name	Habitats								Status	Growth Type
		Riverine/ Herbaceous Riparian	Robust Emer-gent & SAV	Short Emer-gent	Wet Meadow	Alkali/ Saline Wet Meadow	Salt Desert Shrub/ Grass-land	Sage-brush Steppe	Other		
Common Bedstraw	*Galium aparine*	x							x	N	A
Salicaceae											
Plains Cottonwood	*Populus deltoides*								GF	PL	P
Fremont's Cottonwood	*Populus fremontii*								GF	PL	P
Black cottonwood	*Populus trichocarpa*								GF	PL	P
Peachleaf Willow	*Salix amygdaloides*	x							GF	N	P
Coyote Willow	*Salix exigua*	x							GF	N	P
Crack Willow	*Salix fragilis*	x							GF	I	P
Whiplash Willow	*Salix lucida*	x							GF	N	P
Yellow Willow	*Salix lutea*	x							GF	N	P
Wolf Willow	*Salix wolfii*	x							GF	N	P
Sapindaceae											
Boxelder	*Acer negundo*								GF	I	P
Santalaceae											
Bastard Toadflax	*Comandra umbellata*						x	x		N	P
Sacrobataceae											
Black Greasewood	*Sarcobatus vermiculatus*						x	x		N	P
Saxifragaceae											
Bulbous Woodland-star	*Lithophragma glabrum*							x		N	P
Smallflower Woodland-star	*Lithophragma parviflorum*							x		N	P
Slender Woodland Star	*Lithophragma tenellum*							x		N	P
Brook Saxifrage	*Micranthes odontoloma*	x			x					N	P
Scrophulariaceae											
Water Mudwort	*Limosella aquatica*	x			x					N	A,P
Lanceleaf Figwort	*Scrophularia lanceolata*	x			x					N	P
Common Mullein	*Verbascum thapsus*				x			x		I	B
Solanaceae											
Black Henbane	*Hyoscyamus niger*				disturbed areas					I*	A,B
Bittersweet Nightshade	*Solanum dulcamara*	x			x					I	P
Urticaceae											
Stinging nettle	*Urtica dioica*				x		x	x		N	P
Verbenaceae											
Prostrate Vervain	*Verbena bracteata*	x			x			x		N	A,B,P
Swamp Verbena	*Verbena hastata*	x		x	x					N	B,P
Violaceae											
Hoodedspur Violet	*Viola adunca*	x			x					N	P
Goosefoot Violet	*Viola purpurea*							x		N	P
Sagebrush Violet	*Viola vallicola*							x		N	P

Cary Aloia

Appendix B Vertebrate species expected to occur in various habitat types at Camas National Wildlife Refuge (CNWR). For Other Habitat, MMS=man-made structure; Rocky=rocky outcrops; and GF=planted gallery forest (cottonwoods and associated shrubs). For Status,N=native; N?= Native to the Los Rivers drainages but uncertain if it occurred at CNWR; END=native, endemic to Idaho; I=introduced; EXT=locally extirpated; I*=introduced, classified as invasive by the State of Idaho; and C=Federal candidate species. State Rank is provided for native species identified as Species of Greatest Conservation Need (IDFG 2005) as follows: S1=native, State critically imperiled; S2=native, State imperiled; S3=native, State vulnerable to decline; S4=native, apparently secure, though quite rare in parts of its range; and S5=native, demonstrably secure, though frequently quite rare in parts of its range. Qualifiers to State rank include S#N for non-breeding status; S#B for breeding status, and S#M for migratory status. Species list compiled from CNWR Wildlife Checklist and CNWR Draft CCP (USFWS 2014). Species data compiled from Idaho Department of Fish and Game (2005), Froese and Pauly (2011), Poole (2013), Digital Atlas of Idaho (http://imnh.isu.edu/digitalatlas/), Bat Conservation International (http://batcon.org/), and USGS Nonindigenous Aquatic Species Database (http://nas.er.usgs.gov/). Nomenclature follows Integrated Taxonomic Information System (www.itis.gov, accessed May 2013) and Douglas et al. (2002).

		Habitats								
Common Name	*Scientific Name*	Riverine/ Herbaceous Riparian	Robust Emergent/ Submerged Aquatic	Short Emer-gent	Wet Meadow	Alkali/ Saline Wet Meadow	Salt Desert Shrub/ Grass-land	Sage-brush Steppe	Other	Status
FISH										
Utah Chub	*Gila atraria*	x	x	x						N
Utah Sucker	*Catostomus ardens*	x	x	x						N
Brown Bullhead	*Ameiurus nebulosus*	x	x							I
Yellow Perch	*Perca flavescens*	x	x	x						I
Cutthroat Trout	*Oncorhynchus clarki*	x	x							N?
Rainbow Trout	*Oncorhynchus mykiss*	x	x							I
Brook Trout	*Salvelinus fontinalis*	x								I
Mountain Whitefish	*Prosopium williamsoni*	x								N?
Sculpin	*Cottus* sp.	x	x							N
Crappie	*Pomoxis* sp.	x								I
Catfish	[species not reported]	x	x							I
Largemouth Bass	*Micropterus salmoides*	x	x	x						I
AMPHIBIANS										
Anura										
Western Toad	*Anaxyrus boreas*				x	x	x	x		N
Northern Leopard Frog	*Lithobates pipiens*	x	x	x	x				GF	S2
Western Chorus Frog	*Pseudacris triseriata*		x	x	x	x	x	x		N
Great Basin Spadefoot Toad	*Spea intermontana*		x	x	x	x	x	x		N
Caudata										
Tiger Salamander	*Ambystoma tigrinum*	x	x	x	x	x	x	x	GF	N
REPTILES										
Phrynosomatidae										
Sagebrush Lizard	*Sceloporus graciosus*						x	x	MMS Rocky	N
Greater Short-horned Lizard	*Phrynosoma douglasii*				x	x	x	x		N
Scincidae										
Western Skink	*Eumeces skiltonianus*				x	x	x	x	Rocky	N
Colubridae										
Racer	*Coluber constrictor*				x	x	x	x	Rocky	N
Gopher Snake	*Pituophis catenifer*	x	x	x	x	x	x	x	GF	N
Terrestrial Garter Snake	*Thamnophis elegans*	x	x	x	x	x			GF	N
Common Garter Snake	*Thamnophis sirtalis*	x	x	x	x	x			GF	
Ring-necked Snake	*Diadophis punctatus*				x	x	x	x	Rocky	S2
Viperidae										
Western Rattlesnake	*Crotalus oreganus*					x	x	x	Rocky	N
BIRDS										
Gaviiformes										
Common Loon	*Gavia immer*	x	x							S1B,S2N
Podicipediformes										
Horned Grebe	*Podiceps auritus*	x	x							N
Eared Grebe	*Podiceps nigricollis*		x							N
Pied-billed Grebe	*Podylimbus podiceps*	x	x							N
Western Grebe	*Aechmophorus occidentalis*		x							S2B
Clark's Grebe	*Aechmorphorus clarkii*		x							S2B
Pelicaniformes										

Continued next page

Appendix B, continued.

Common Name	Scientific Name	Habitats: Riverine/ Herbaceous Riparian	Robust Emergent/ Submerged Aquatic	Short Emer-gent	Wet Meadow	Alkali/ Saline Wet Meadow	Salt Desert Shrub/ Grass-land	Sage-brush Steppe	Other	Status
American White Pelican	*Pelecanus erythrorhynchos*	x	x							S1B
Double-crested Cormorant	*Phalacrocorax auritus*	x	x						GF	N
Ciconiformes										
American Bittern	*Botaurus lentiginosus*		x	x						N
Great Blue Heron	*Ardea herodias*	x	x	x						N
Great Egret	*Ardea alba*	x	x	x	x					S1B
Snowy Egret	*Egretta caerulea*	x	x	x	x					S2B
Cattle Egret	*Bubulcus ibis*	x	x	x	x					S2B
Black-crowned Night Heron	*Nycticorax nycticorax*	x	x	x	x	x				S2B
White-faced Ibis	*Plegadis chihi*		x	x	x	x				S2B
Anseriformes										
Trumpeter Swan	*Cygnus buccinator*	x	x	x						S1B,S2N
Tundra Swan	*Cygnus columbianus*	x	x	x						N
Canada Goose	*Branta canadensis*	x	x	x	x	x	x			N
Greater White-fronted Goose	*Anser albifrons*	x	x	x	x	x	x			N
Ross's Goose	*Chen rossi*	x	x	x	x	x	x			N
Lesser Snow Goose	*Chen caerulescens*	x	x	x	x	x	x			N
Wood Duck	*Aix sponsa*	x	x						GF	N
Mallard	*Anas platyrhunchos*	x	x	x	x	x	x	x		N
Gadwall	*Anas strepera*	x	x	x	x	x				N
Northern Pintail	*Anas acuta*	x	x	x	x	x				S5B,S2N
American Wigeon	*Anas americana*	x	x	x	x	x	x	x		N
Northern Shoveler	*Anas clypeata*	x	x	x	x	x	x	x		N
Cinnamon Teal	*Anas cyanoptera*	x	x	x	x	x				N
Blue-winged Teal	*Anas discors*	x	x	x	x	x				N
Green-winged Teal	*Anas crecca*	x	x	x	x	x	x	x		N
Canvasback	*Aythya valisineria*	x	x							N
Redhead	*Aythya americana*	x	x	x	x	x				N
Ring-necked Duck	*Aythya collaris*	x	x							N
Lesser Scaup	*Aythya affinis*	x	x	x	x	x	x	x		S3
Greater Scaup	*Aythya marila*	x	x							N
Common Goldeneye	*Bucephala clangula*	x	x							N
Barrow's Goldeneye	*Bucephala islandica*	x	x							N
Bufflehead	*Bucephala albeola*	x	x							N
Hooded Merganser	*Lophodytes cucullatus*	x	x							S2B,S3N
Common Merganser	*Mergus merganser*	x	x							N
Red-breasted Merganser	*Mergus serrator*	x	x							N
Ruddy Duck	*Oxyura jamaicensis*	x	x							N
Falconiformes										
Turkey Vulture	*Cathartes aura*	x	x	x	x	x	x	x	Rocky GF	N
Northern Harrier	*Circus cyaneus*	x	x	x	x	x	x	x	GF	N
Sharp-shinned Hawk	*Accipiter striatus*	x					x	x	GF	N
Cooper's Hawk	*Accipiter coperii*	x							GF	N
Northern Goshawk	*Accipiter gentillis*	x				x	x	x	GF	N
Swainson's Hawk	*Buteo swainsoni*				x	x	x	x		S3B
Red-tailed Hawk	*Buteo jamaicensis*	x	x	x	x	x	x	x	GF	N
Ferruginous Hawk	*Buteo regalis*	x	x	x	x	x	x	x	GF	S3B
Rough-legged Hawk	*Buteo lagopus*	x	x	x	x	x	x	x	GF	N
Golden Eagle	*Aquilla cyrysaetos*	x	x	x	x	x	x	x	GF	N
Bald Eagle	*Haliaeetus leucocephalus*	x	x	x	x	x	x	x	GF	S3B,S4N
Osprey	*Pandion haliaetus*	x	x						GF	N
Merlin	*Falco columbarius*	x	x	x	x	x	x	x	GF	S2B,S2N
American Kestrel	*Falco sparverius*				x	x	x	x		N
Prairie Falcon	*Falco mexicanus*				x	x	x	x		N
Peregrine Falcon	*Falco peregrinus*	x	x	x	x	x	x	x	MMS GF	S2B

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Appendix B, continued.

Common Name	Scientific Name	Habitats: Riverine/ Herbaceous Riparian	Robust Emergent/ Submerged Aquatic	Short Emer-gent	Wet Meadow	Alkali/ Saline Wet Meadow	Salt Desert Shrub/ Grass-land	Sage-brush Steppe	Other	Status
Galliformes										
Greater Sage-grouse	*Centrocercus urophasianus*				x	x	x	x		C S2
Gray Partridge	*Perdix perdix*	x			x	x			GF	I
Ring-necked Pheasant	*Phasianus colchicus*	x			x	x	x	x	GF	I
Gruiformes										
American Coot	*Fulica americana*	x	x	x						N
Virginia Rail	*Rallus limicola*		x	x	x					N
Sora	*Porzana carolina*		x	x	x					N
Sandhill Crane	*Grus canadensis*	x	x	x	x	x	x	x		S2B
Charadriiformes										
Black-bellied Plover	*Pluvialis squatarola*				x	x			Rocky	N
Semipalmated Plover	*Charadrius semipalmatus*				x	x				N
Killdeer	*Charadrius vociferous*				x	x			Rocky	N
American Avocet	*Recurvirostra americana*		x	x	x	x	x	x		S5B
Black-necked Stilt	*Himantopus mexicanus*		x	x	x	x				S3B
Greater Yellowlegs	*Tringa melanoleuca*	x	x	x	x	x				N
Lesser Yellowlegs	*Tringa flavipes*	x	x	x	x	x				N
Solitary Sandpiper	*Tringa solitaria*				x	x				N
Willet	*Tringa semipalmata*	x			x	x				N
Spotted Sandpiper	*Actitis macularia*	x		x	x	x	x	x		N
Long-billed Curlew	*Numenius americanus*				x	x	x	x		S2B
Marbled Godwit	*Limosa fedoa*		x	x	x	x				N
Baird's Sandpiper	*Calidris bairdii*			x	x	x				N
Stilt Sandpiper	*Calidris himantopus*			x	x	x				N
Western Sandpiper	*Calidris mauri*		x	x	x	x				N
Pectoral Sandpiper	*Calidris melanotos*				x	x				N
Least Sandpiper	*Calidris minutilla*		x	x	x	x				N
Semipalmated Sandpiper	*Calidris pusilla*				x	x				N
Long-billed Dowitcher	*Limnodromus scolopaceus*	x			x	x				N
Wilson's Snipe	*Gallinago delicata*	x		x	x	x				N
Wilson's Phalarope	*Phalaropus tricolor*	x	x	x	x	x				S3B
Red-necked Phalarope	*Phalaropus lobatus*	x	x							N
Bonaparte's Gull	*Chroicocephalus philadelphia*	x	x	x						N
Franklin's Gull	*Leucophaeus pipixcan*		x	x	x	x				S2B
Ring-billed Gull	*Larus delawarensis*		x	x	x	x				N
California Gull	*Larus californicus*		x	x	x	x	x	x		S2B,S3N
Caspian Tern	*Hydroprogne caspia*	x	x							S2B
Forster's Tern	*Sterna forsteri*	x	x							S1B
Common Tern	*Sterna hirundo*		x	x	x	x				N
Black Tern	*Chlidonias niger*		x	x	x	x				S1B
Columbiformes										
Mourning Dove	*Zenaida macroura*	x	x	x	x	x	x	x	GF	N
Rock Pigeon	*Columbia livia*						x	x	MMS	I
Strigiformes										
Barn Owl	*Tyto alba*	x	x	x	x	x	x	x	MMS GF	N
Long-eared Owl	*Asio otus*	x	x	x	x	x	x	x	GF	N
Short-eared Owl	*Asio flammeus*	x	x	x	x	x	x	x	GF	S4
Great-horned Owl	*Bubo virginianus*	x	x	x	x	x	x	x	GF	N
Northern Saw-whet Owl	*Aegolius acadicus*						x	x		N
Burrowing Owl	*Athene cunicularia*				x	x	x	x		S2B
Great Gray Owl	*Strix nebulosa*								GF	N
Caprimulgiformes										
Common Nighthawk	*Chordeiles minor*	x	x	x	x	x	x	x	Rocky GF	N
Common Poorwill	*Phalaenoptilus nuttallii*				x	x	x	x	Rocky	N

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Appendix B, continued.

Common Name	Scientific Name	Habitats: Riverine/ Herbaceous Riparian	Robust Emergent/ Submerged Aquatic	Short Emer-gent	Wet Meadow	Alkali/ Saline Wet Meadow	Salt Desert Shrub/ Grass-land	Sage-brush Steppe	Other	Status
Apodiformes										
Black-chinned Hummingbird	*Archilochus alexandri*						x	x		N
Calliope Hummingbird	*Stellula calliope*	x			x	x	x	x	GF	N
Broad-tailed Hummingbird	*Selasphorus platycercus*	x							GF	N
Rufous Hummingbird	*Selasphorus rufus*	x			x		x	x	GF	N
Coraciformes										
Belted Kingfisher	*Megaceryle alcyon*	x	x						GF	N
Piciformes										
Lewis's Woodpecker	*Melanerpes lewis*								GF	S3B
Red-naped Sapsucker	*Sphyrapicus nuchalis*								GF	N
Williamson's Sapsucker	*Sphyrapicus thyroideus*								GF	N
Downy Woodpecker	*Picoides pubescens*								GF	N
Hairy Woodpecker	*Picoides villosus*								GF	N
Three-toed Woodpecker	*Picoides dorsalis*								GF	S2
Northern Flicker	*Colaptes auratus*								GF	N
Passeriformes										
Olive-sided Flycatcher	*Contopus cooperi*	x							GF	N
Western Wood-pewee	*Contopus sordidulus*	x						x	GF	N
Cordilleran Flycatcher	*Empidonax occidentalis*	x							GF	N
Willow Flycatcher	*Empidonax traillii*	x							GF	N
Gray Flycatcher	*Empidonax wrightii*						x	x		N
Hammond's Flycatcher	*Empidonax hammondii*						x	x		N
Dusky Flycatcher	*Empidonax oberholseri*						x	x		N
Least Flycatcher	*Empidonax minimus*	x						x	GF	N
Western Kingbird	*Tyrannus verticalis*	x			x	x	x	x	MMS	N
Eastern Kingbird	*Tyrannus tyrannus*									N
Northern Shrike	*Lanius excubitor*	x			x	x	x	x	GF	N
Loggerhead Shrike	*Lanius ludovicianus*	x			x	x	x	x	GF	N
Red-eyed Vireo	*Vireo olivaceus*	x							GF	N
Warbling Vireo	*Vireo gilvus*	x					x	x	GF	N
Plumbeous Vireo	*Vireo plumbeus*	x							GF	N
Cassin's Vireo	*Vireo cassinii*	x							GF	N
Steller's Jay	*Cyanocitta stelleri*	x							GF	N
Clark's Nutcracker	*Nucifraga columbiana*	x							GF	N
Black-billed Magpie	*Pica hudsonia*	x	x	x	x	x	x	x	MMS GF	N
American Crow	*Corvus brachyrhynchos*	x	x	x	x	x	x	x	MMS GF	N
Common Raven	*Corvus corax*	x	x	x	x	x	x	x	MMS GF	N
Horned Lark	*Eremophila alpestris*	x			x	x	x	x	GF	N
Northern Rough-winged Swallow	*Stelgidopteryx serripennis*	x	x	x	x	x	x	x	MMS GF	N
Bank Swallow	*Riparia ripiria*	x	x	x	x	x	x	x	MMS GF	N
Violet-green Swallow	*Tachycineta thalassina*	x		x	x	x			GF	N
Tree Swallow	*Tachycineta bicolor*	x	x	x	x	x	x	x	GF	N
Cliff Swallow	*Petrochelidon pyrrhonota*	x	x	x	x	x			MMS GF	N
Barn Swallow	*Hirundo rustica*	x	x	x	x	x	x	x	MMS GF	N
Black-capped Chickadee	*Poecile atricapillus*							x	GF	N
Mountain Chickadee	*Poecile gambeli*								GF	N
Red-breasted Nuthatch	*Sitta canadensis*							x	GF	N
White-breasted Nuthatch	*Sitta carolinensis*							x	GF	N
Brown Creeper	*Certhia americana*								GF	N

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Appendix B, continued.

Common Name	Scientific Name	Habitats: Riverine/ Herbaceous Riparian	Robust Emergent/ Submerged Aquatic	Short Emer-gent	Wet Meadow	Alkali/ Saline Wet Meadow	Salt Desert Shrub/ Grass-land	Sage-brush Steppe	Other	Status
Rock Wren	*Salpinctes obsoletus*						x	x	Rocky	N
House Wren	*Troglodytes aedon*							x	GF	N
Winter Wren	*Troglodytes hiemalis*	x								N
Marsh Wren	*Cistothorus palustris*	x	x	x						N
Golden-crowned Kinglet	*Regulus satrapa*	x							GF	N
Ruby-crowned Kinglet	*Regulus calendula*	x							GF	N
Blue-gray Gnatcatcher	*Polioptila caerulea*	x						x	GF	N
Townsend's Solitaire	*Myadestes townsendi*							x	GF	N
Mountain Bluebird	*Sialia currucoides*						x	x		N
American Robin	*Turdus migratorius*						x	x	MMS	N
Veery	*Catharus fuscescens*								GF	N
Swainson's Thrush	*Catharus ustulatus*							x	GF	N
Hermit Thrush	*Catharus guttatus*								GF	N
Ovenbird	*Seiurus aurocapilla*							x	GF	N
Gray Catbird	*Dumetella carolinensis*						x	x		N
Sage Thrasher	*Oreoscoptes montanus*						x	x		N
European Starling	*Sturnus vulgaris*	x			x	x	x	x	MMS	I
American Pipit	*Anthus rubescens*	x			x	x			GF	N
Bohemian Waxwing	*Bombycilla garrulus*	x					x	x	GF	N
Cedar Waxwing	*Bombycilla cedrorum*	x					x	x	GF	N
Nashville Warbler	*Oreothlypis ruficapilla*						x	x	GF	N
Orange-crowned Warbler	*Oreothlypis celata*	x							GF	N
Yellow Warbler	*Setophaga petechia*	x					x	x	GF	N
Yellow-rumped Warbler	*Dendroica coronata*	x	x				x	x	MMS GF	N
Black-throated Gray Warbler	*Dendroica nigrescens*								GF	N
Blackpoll Warbler	*Dendroica striata*								GF	N
Townsend's Warbler	*Dendroica townsendi*								GF	N
American Redstart	*Setophaga ruticilla*								GF	N
Northern Waterthrush	*Parkesia noveboracensis*	x	x	x						N
MacGillivray's Warbler	*Oporornis tolmiei*	x							GF	N
Common Yellowthroat	*Geothlypis trichas*		x	x	x	x	x	x		N
Wilson's Warbler	*Cardellina pusilla*	x					x	x	GF	N
Yellow-breasted Chat	*Icteria virens*	x							GF	N
Western Tanager	*Piranga ludoviciana*	x					x	x	GF	N
Rose-breasted Grosbeak	*Pheucticus ludovicianus*	x	x				x	x	GF	N
Black-headed Grosbeak	*Pheucticus melanocephalus*	x							GF	N
Lazuli Bunting	*Passerina amoena*						x	x		N
Green-tailed Towhee	*Pipilo chlorurus*						x	x		N
Spotted Towhee	*Pipilo maculatus*						x	x		N
American Tree Sparrow	*Spizella arborea*	x	x	x	x	x	x	x	MMS GF	N
Chipping Sparrow	*Spizella passerina*	x			x		x	x	GF	N
Brewer's Sparrow	*Spizella breweri*						x	x		S3B
Vesper Sparrow	*Pooecetes gramineus*				x	x	x	x		N
Lark Sparrow	*Chondestes grammacus*	x			x	x	x	x	GF	N
Sage Sparrow	*Artemisiospiza belli*						x	x		N
Savannah Sparrow	*Passerculus sandwichensis*	x		x	x	x	x		GF	N
Grasshopper Sparrow	*Ammodramus savannarum*				x	x	x	x		S2B
Fox Sparrow	*Passerella iliaca*	x							GF	N
Song Sparrow	*Melospiza melodia*	x	x	x	x	x	x	x	GF	N
Lincoln's Sparrow	*Melospiza lincolnii*	x					x	x	GF	N
White-throated Sparrow	*Zonotrichia albicollis*	x					x	x	GF	N
White-crowned Sparrow	*Zonotrichia leucophrys*	x			x	x	x	x	GF	N

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Appendix B, continued.

Common Name	Scientific Name	Habitats: Riverine/ Herbaceous Riparian	Robust Emergent/ Submerged Aquatic	Short Emer-gent	Wet Meadow	Alkali/ Saline Wet Meadow	Salt Desert Shrub/ Grass-land	Sage-brush Steppe	Other	Status
Dark-eyed Junco	*Junco hyemalis*						x	x		N
Snow Bunting	*Plectrophenax nivalis*	x		x	x	x				N
Western Meadowlark	*Sturnella neglecta*	x			x	x	x	x	GF	N
Brown-headed Cowbird	*Molothrus ater*	x	x	x	x	x	x	x	GF	N
Yellow-headed Blackbird	*Xanthocephalus xantheocephalus*	x	x	x	x	x				N
Red-winged Blackbird	*Agelaius phoeniceus*	x	x	x	x	x				N
Brewer's Blackbird	*Euphagus cyanocephalus*	x	x	x	x	x	x	x	GF	N
Common Grackle	*Quiscalus quiscula*	x	x	x	x	x		x	GF	N
Bullock's Oriole	*Icterus bullockii*	x							GF	N
Evening Grosbeak	*Coccothraustes vespertinus*								GF	N
Common Redpoll	*Acanthis flammea*	x		x	x	x	x	x	GF	N
Cassin's Finch	*Carpodacus cassinii*							x	GF	N
House Finch	*Carpodacus mexicanus*	x					x	x	MMS GF	N
Pine Siskin	*Spinus pinus*				x	x	x	x		N
American Goldfinch	*Spinus tristis*	x			x	x	x	x	GF	N
House Sparrow	*Passer domesticus*								MMS	I
MAMMALS										
Insectivora										
Vagrant Shrew	*Sorex vagrans*	x			x	x	x	x	GF	N
Merriam's Shrew	*Sorex merriami*				x	x	x	x		S2
Water Shrew	*Sorex palustris*	x								N
Chiroptera										
Western Small-footed Myotis	*Myotis ciliolabrum*		x	x	x	x	x	x		N
Little Brown Bat	*Myotis lucifugus*	x	x	x	x	x	x	x	MMS GF	N
Yuma Myotis	*Myotis yumanensis*	x	x	x	x	x			MMS GF	N
Big Brown Bat	*Eptesicus fuscus*	x	x	x	x	x	x	x	MMS GF	N
Spotted Bat	*Euderma maculatum*		x	x	x	x	x	x	MMS	S3
Townsend's Big-eared Bat	*Corynorhinus townsendii*				x	x	x	x	MMS	S3
Rodentia										
Yellow-bellied Marmot	*Marmota flaviventris*				x	x	x	x	Rocky	N
Townsend's Ground Squirrel	*Spermophilus townsendii*						x	x		N
Wyoming Ground Squirrel	*Spermophilus elegans*				x	x	x	x		S3
Uinta Ground Squirrel	*Spermophilus armatus*				x	x	x			N
Great Basin/Piute Ground Squirrel	*Spermophilus mollis*						x	x		S2
Least Chipmunk	*Tamias minimus*	x			x	x	x	x	GF	N
Idaho Pocket Gopher	*Thomomys idahoensis*				x	x	x	x		S3
Northern Pocket Gopher	*Thomomys talpoides*	x			x	x	x	x	GF	N
Great Basin Pocket Mouse	*Perognathus parvus*						x	x		N
Ord's Kangaroo Rat	*Dipodomys ordii*				x	x	x	x		N
Beaver	*Castor canadensis*	x	x						GF	N
Western Harvest Mouse	*Reithrodontomys megalotis*	x	x	x	x	x	x	x	GF	N
Deer Mouse	*Peromyscus maniculatus*	x	x	x	x	x	x	x	GF	N
Northern Grasshopper Mouse	*Onychomys leucogaster*				x	x		x		N
Bushy-tailed Woodrat	*Neotoma cinerea*						x	x	Rocky	N
Meadow Vole										
Montane Vole	*Microtus montanus*	x			x	x		x	GF	N
Sagebrush Vole	*Lemmiscus curtatus*							x		N

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Appendix B, continued.

Common Name	Scientific Name	Habitats: Riverine/ Herbaceous Riparian	Robust Emergent/ Submerged Aquatic	Short Emer-gent	Wet Meadow	Alkali/ Saline Wet Meadow	Salt Desert Shrub/ Grass-land	Sage-brush Steppe	Other	Status
Muskrat	*Ondatra zibethicus*	x	x	x						N
House Mouse	*Mus musculus*								MMS	I
Western Jumping Mouse	*Zapus princeps*	x			x	x			GF	N
Porcupine	*Erethizon dorsatum*				x	x	x	x		N
Lagomorpha										
White-tailed Jackrabbit	*Lepus townsendii*				x	x	x	x		N
Black-tailed Jackrabbit	*Lepus californicus*						x	x		N
Mountain Cottontail	*Sylvilagus nuttallii*							x		N
Pygmy Rabbit	*Brachylagus idahoensis*							x		S2
Carnivora										
Coyote	*Canis latrans*	x	x	x	x	x	x	x	GF	N
Gray Wolf	*Canis lupus*	x		x	x	x	x	x	GF	S3
Domestic Dog	*Canis lupus familiaris*			x	x	x	x	x		I
Red Fox	*Vulpes vulpes*	x	x	x	x	x	x	x	GF	N
Short-tailed Weasel or Ermine	*Mustela erminea*	x	x	x	x	x	x	x	GF	N
Long-tailed Weasel	*Mustela frenata*	x	x	x	x	x	x	x	GF	N
Mink	*Mustela vison*	x	x							N
American Badger	*Taxidea taxus*				x	x	x	x		N
Western Spotted Skunk	*Spilogale gracilis*	x			x	x	x	x	GF	N
Striped Skunk	*Mephitis mephitis*		x	x	x	x	x	x	MMS	N
Mountain Lion	*Puma concolor*						x	x		N
Domestic Cat	*Felis catus*			x	x	x	x	x		I
Bobcat	*Lynx rufus*			x	x	x	x	x		N
Black Bear	*Ursus americanus*	x		x	x	x	x	x	GF	N
River Otter	*Lontra canadensis*	x								N
Artiodactyla										
Elk	*Cervus elaphus*	x			x	x	x	x	GF	N
Mule Deer	*Odocoileus hemionus*	x			x	x	x	x	GF	N
White-tailed Deer	*Odocoileus virginianus*	x	x	x	x				GF	N
Pronghorn	*Antilocapra americana*	x			x	x	x	x		N
Moose	*Alces alces*	x	x	x	x				GF	N
American Bison	*Bison bison*			x	x	x	x	x		EXT
Bighorn Sheep	*Ovis canadensi*							x		N